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Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

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Pioneering With Motor Drives—

A Little History and a Record of Motor Performance That Will Be Hard to Beat

HUNDREDS and even thousands of small motors in a single textile mill driving looms and spinning frames now create little comment.

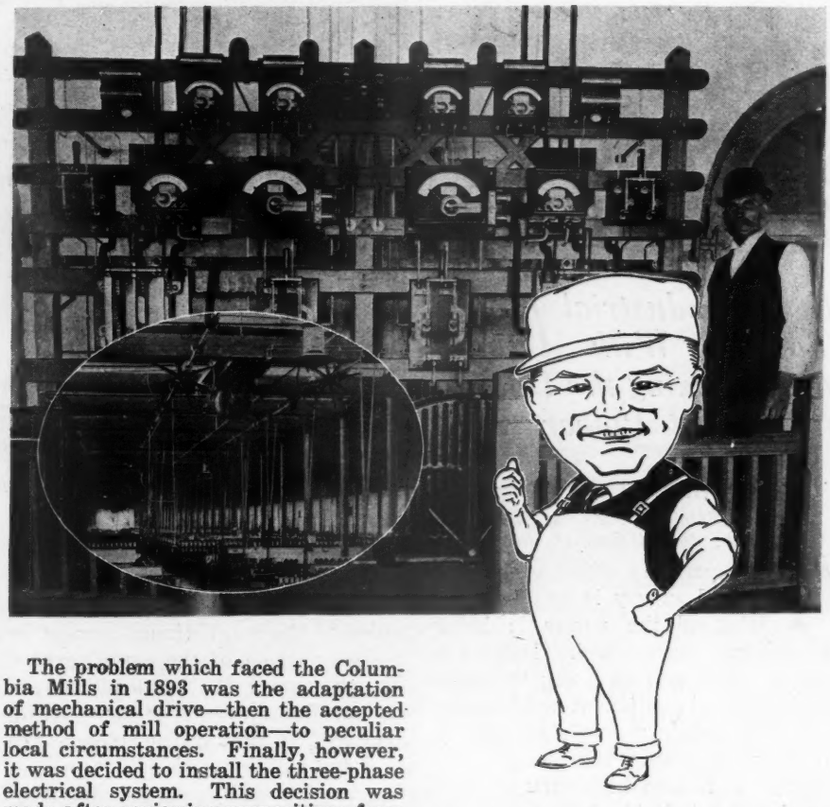
From an electrical standpoint, this industry is today well toward the top of the list from the standpoint of number of motors operated, largely because of the opportunity to use individual drive on textile machines.

And all of this has happened during the past 30 years. At the plant of the Columbia Mills at Columbia, S. C., the first application of an induction motor drive was made in a textile mill, and this was the first such mill in the world to install a complete generating plant for operating motors on the premises and to adopt the plan of subdividing the mill into independently-driven sections.

The photographs show one of the first induction motor drives in the plant of the Columbia Mills, and an old, wood-frame switchboard installed in the power station.

Another interesting point about this installation is that the original electrical equipment is still running and giving satisfactory service. Of the fourteen motors installed, only seven have been rewound and five of them are running on their original sleeve bearings.

In checking up with the Engineering Department of the General Electric Company on this motor installation, I have received the following comment:



The problem which faced the Columbia Mills in 1893 was the adaptation of mechanical drive—then the accepted method of mill operation—to peculiar local circumstances. Finally, however, it was decided to install the three-phase electrical system. This decision was made after reviewing propositions from three competitive manufacturers, two of whom suggested the use of direct-current motors of large size to drive the shafting which would ordinarily be used in a mechanically-driven mill. In April, 1894, two 500-kw., 108-r.p.m., 3-phase generators direct connected to two pairs of 48-in. horizontal water wheels were installed and fourteen 65-hp. induction motors were used for operating the mill.

At the time the installation was made there was no record of any motor having been used in a cotton mill. These motors were the first to be inverted and suspended from the ceiling, and it was the first instance where a motor shaft was extended at both ends.

The normal rating of the motors when installed was 65 hp. each. During their thirty-two years of operation the average load has been from 80 to 85 hp. Rewinding has been actually necessary on but five of the stators, two having recently been rewound as a precautionary measure. The only repairs needed by the motors were of a minor character. Some of the motors were run, in addition to their thirty-two years of day operation, for at least ten years on night operation, giving an equivalent of forty-two years of service since the original installation.

At the time the motors were installed they were the largest of that type in horsepower rating which the General Electric Company had made. The largest three-phase induction motors built before that time were 10-hp. machines, a single 5-hp. unit being the largest sold.

Credit for this piece of pioneering goes to C. K. Oliver who ordered the equipment in 1893, and Sidney B. Paine, who handled the work for the General Electric Company, with the late Charles P. Steinmetz in the background as a combined engineer and salesman. It is on the results of such pioneer work as this that mill and factory electrification today owes its rapid progress and no one would dare predict now just what it will be like in extent or nature thirty-two years from now.

Practical Pete

A LOAD SURVEY of an industrial plant will often expose conditions which cause the power cost to be higher than necessary. Perhaps the diversity factor may be improved so as to cut down the maximum demand. Possibly the connected-load factor will indicate an over-investment in drive equipment. Again, power factor investigations may disclose ways to cut power costs. In this article Mr. Stafford tells how to determine and use these factors to interpret load conditions in your plant.

How to Go About

Making a Survey of the Power Load

In an Industrial Works Together With Methods of Analyzing the Data so as to Cut Power Costs

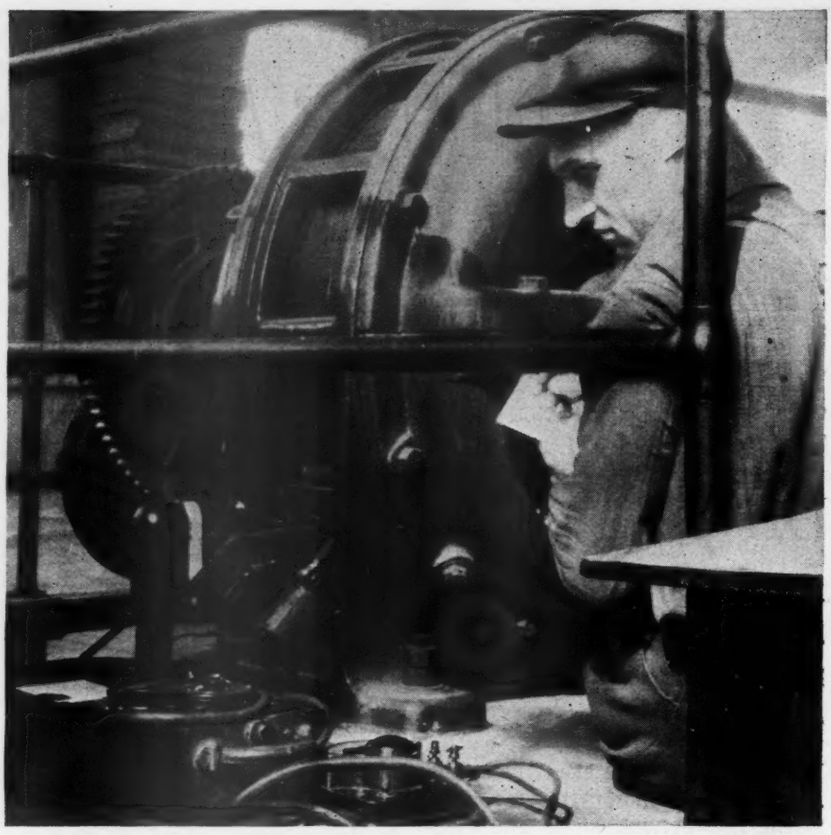


Fig. 1. A check is being made of the voltage and current supplied to this motor.

Less than rated voltage lessens the torque developed by the motor, which causes it to run at less than rated speed. Comparison of the ammeter reading with the ampere rating given on the nameplate of the motor will show whether or not the motor is overloaded and in danger of overheating. The ammeter reading does not give a true indication of the power developed by the motor unless used in connection with the efficiency and power factor curves of the motor.

By H. E. STAFFORD

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THE primary object of making a load survey is to determine whether the power is being economically consumed. Making a survey involves measuring the loads on individual equipment and locating and determining any electrical or mechanical losses that may exist there. It is also necessary to summarize the individual loads so that they can be analyzed and comparisons drawn by means of the following factors: power factor, load factor, connected-load factor, demand factor, plant factor, and diversity factor. These factors are all expressed as percentages and it is through an interpretation of these factors and the losses found from the survey that conclusions may be reached as to whether the power consumed is being used economically.

Before taking up in detail the factors just mentioned, let us consider some of the mechanical and electrical losses that may be found in the average industrial plant.

The mechanical losses in power consumption are usually termed the friction load and will vary with each type of mechanical drive and with each individual unit. The least friction load is found where the drive is direct through a coupling, as with most centrifugal pump installations. Here, the friction load consists merely of the bearing and running plate friction and should not, when added to the magnetizing current or no-load current of the motor, exceed 20 per cent of the full-load current rating. For convenience, the friction load will, in this article, include the load due to the magnetizing current.

Gears of various forms constitute a friction load slightly in excess of the coupling drive, with an average of approximately 20.5 per cent of the full-load current rating of the motor. Gears should mesh properly; otherwise the friction load will increase considerably above normal.

Rope, chain and belt drives produce a greater friction load than those drives mentioned above, even under the most advantageous circumstances. The friction load with these types will reach as high as 30 per cent of the full-load current rating unless carefully checked. The average should not exceed 25 per cent even with lineshafting, if the use of power is to be considered economical. Where the connecting link is a chain it should have a certain amount of play and should never be tight, as a tight chain has no give or elasticity and imposes an excess of friction load, besides lessening the life of the bearings and chain.

With rope drives, the most economical method of saving power or reducing the friction load and preventing slippage, is by means of counterweight pulleys, the weight of which can be increased or decreased until a point is reached where both the slippage and friction load are minimum.

Where leather or composition belts are used, considerable losses may result unless belt tension is properly adjusted and the proper size of belts and pulleys is used.

Lineshafting is the cause of a heavy friction load in many cases; consequently, a great amount of care should be taken in its installation, particularly as regards alignment and the type of bearings used. Ball and roller bearings, while more expensive in first cost, will usually make up for the extra cost in re-

duced friction load, lessened lubrication and lower maintenance costs.

Considerable power is lost in a great number of cases due to improper size of pulleys. The pulley furnished with the motor should not be changed without studying the application carefully, since the size furnished will in all cases be the most suitable for the type of motor. In 99 cases out of 100, haphazard changing of pulleys results in increased friction load, and is often disastrous to the motor.

The mechanical losses that have just been described can be readily checked by connecting a wattmeter, ammeter, and voltmeter in the individual motor circuits and noting the effect of any mechanical readjustments on the load taken by the motor under test.

Besides the mechanical losses that have just been discussed, there are some electrical losses that should be considered in making a load survey.

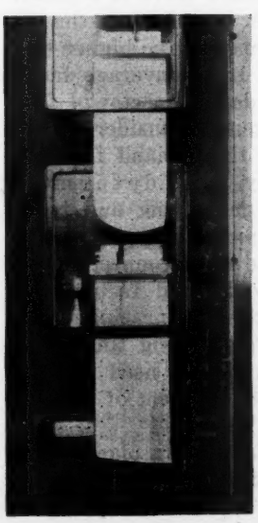
The electrical losses of a system using direct-current motors do not increase the cost of power to the same extent as when alternating-current motors are used, and apart from the losses due to field excitation, they may be ignored. The field excitation, however, is practically the same at all loads and does not vary greatly with the size of the motor. For instance, the field amperes of a 30-hp., and a 55-hp., direct-current motor are identical. Where motors are underloaded, there is a slight mechanical or friction load which can be reduced by using the proper size of motor. Apart from the losses mentioned above, the remaining losses may all be considered as mechanical losses.

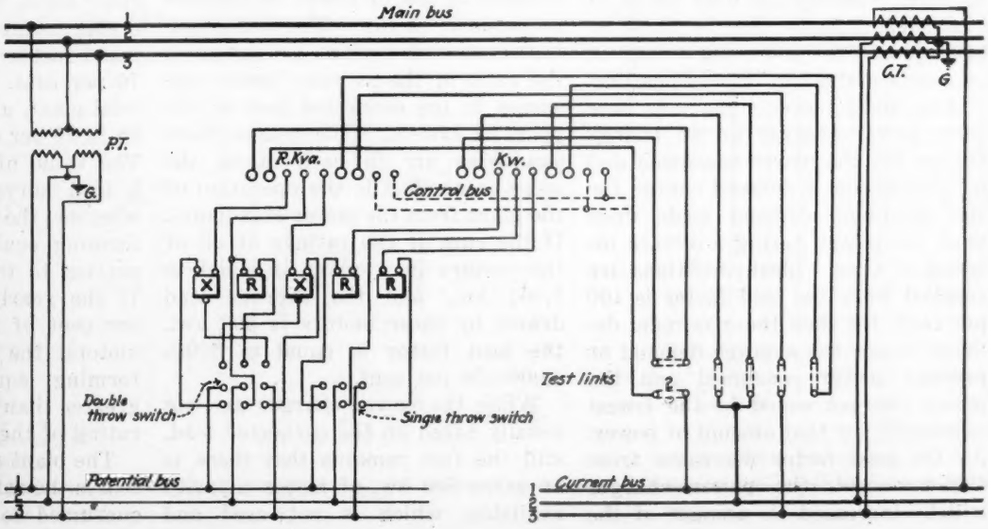
Where alternating current is used, the case is somewhat different. Since alternating-current motors operate on the principle of induction, there is considerable loss due to the magnetizing current in the windings, even in a motor running without load. The writer has found cases where the no-load current of an induction motor was 25 per cent of the full-load rating, and cases where it amounts to 20 per cent are common. On a recent test of a 175-hp. induction motor, with a full-load rating of 176 amp., the losses averaged 37.5 amp. per phase, or 21.3 per cent of the full-load rating.

As this magnetizing current is present at all times when the motor is running, and in almost unvarying quantity, it becomes an important loss if, for instance, the motor is carrying only 50 to 75 per cent of its normal load most of the time. It should be a well-known fact among users of induction motors that an underloaded induction motor is an undesirable quantity. In the first place, the power taken by an induction motor consists of two components. One is an energy component, which is expressed as useful or available power, while the other, which is due to the magnetizing current required by the motor, is called the wattless or reactive component. This latter component is capable of no work and may, therefore, be considered a loss. The ratio of the two components determines the power factor of the load.

In a general sense, the power factor of a motor or a system of motors really expresses the ratio of the power consumed to the power paid for. For this reason power factor is usually considered of primary importance in a load survey.

Most power producing utilities penalize their customers when their power factor falls below a certain percentage, usually 90 per cent lagging. Assuming that a power consumer is using 6,000 hp. at a system power factor of 75 per cent lagging, the basis of charge is then made on the difference between the power factor maintained and that called for, or $6{,}000 \div 0.75 = 8{,}000$. Thus, it may be seen that with a 6,000-hp. load at 75 per cent power factor, 8,000 hp. of transformer capacity, transmission line capacity and electric generator capacity are being used by the power company to supply this power consumer's load. However, since the power company usually does not penalize for that load between 90 and 100 per cent power factor, the load for which the consumer is charged is $8{,}000 \times 0.90 = 7{,}200$ hp., that is, he is charged for 1,200 hp. more than is actually used. The excess of 1,200 hp. consists mainly of the magnetizing current of the load previously mentioned and for which the power company has to maintain equipment. This excess





Figs. 2 and 3. Scheme for using two wattmeters for measuring power and reactive kilovolt-amperes.

Fig. 2 shows two graphic wattmeters, the top one of which is connected so as to measure true power; the wattmeter at the bottom has its potential coils connected so that the current and potential of this meter are in quadrature, thereby causing it to measure reactive kilovolt-amperes. Fig. 3 shows the connection scheme used. The terminals marked Kw. are the current and potential terminals for the wattmeter measuring true power, while the terminals marked R. Kva. are for the wattmeter measuring reactive kilovolt-amperes. The test links and switches shown in both figures are for quickly changing the connections of the R. Kva. meter so as to measure true power instead of reactive kilovolt-amperes.

horsepower is not true power in the sense that it is actual delivered power; it is reactive power and ties up part of the capacity of the equipment generating, distributing or transforming the power.

Low power factor may be remedied by increasing the load on the individual motor or by the installation of either synchronous motors, or static condensers. Individual induction motors should not be overloaded beyond 10 per cent of their rating, as considerable of the overload is made up of an increase in magnetizing current, and while the power factor will increase even after full load is reached, the life of the motor is shortened. The methods of measuring power factor will be discussed later in this article.

Second in importance to power factor in making a load survey is the load factor.

The load factor of a plant or system is the ratio of the average power consumed to the maximum demand on the system for a specified period of time. Load factors may be determined by the month or year, the yearly load factor usually being the one considered in a load survey. In an industrial plant manufacturing a given article, where the duty cycle of the various machines is uniform, the load factor should be fairly high; in some cases as high as 80 per cent. The average manufacturing plant should have a yearly load factor of from 50 to 65 per cent. Plants such as grain elevators, coal and ore docks and others where the duty cycle is seasonal have load factors as low as 15 per cent. The value of this factor in the economical use of power and reduction of losses, lies in the fact that once determined, steps may be taken whereby the duty cycles of some departments may be made to overlap, and the power curve kept in as nearly a straight line as possible.

Also, most power companies base their power charges on an energy charge for the power consumed and in addition, on a demand charge for the maximum demand made upon them for power during a certain interval of time. Ideal conditions are reached when the load factor is 100 per cent, for then the maximum demand equals the average demand or average power consumed and the power charges would be the lowest obtainable for that amount of power. As the load factor decreases from 100 per cent, the power charges will be increased on account of the increase in the demand charge.

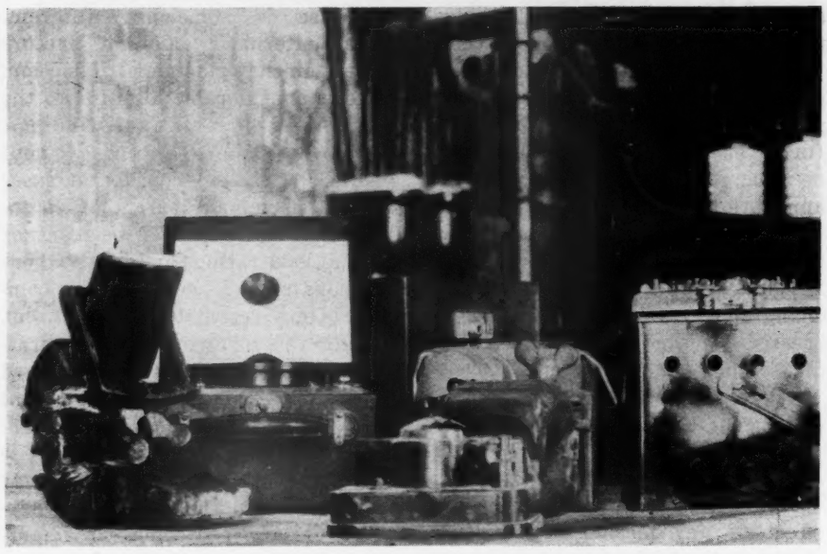


Fig. 4—Here are some of the portable testing instruments used in one industrial plant.

At the left is a split core current transformer having two ratios, one of 25 to 1 and the other 50 to 1. Immediately to the right is a voltmeter having a 300-volt and a 600-volt scale. In the center foreground is an ammeter having a 5-amp. scale for use with a current transformer, one of which is immediately behind it. Behind the current transformer is a megger for use in measuring insulation resistance and other resistance. At the extreme right is a solid core current transformer having 5 to 1, 10 to 1, and 20 to 1 ratios.

The average load, as used in calculating the load factor, is determined by dividing the total kilowatt-hours consumed during a certain period by the number of hours during that period. This gives the average kilowatt-hours per hour which is equivalent to the average kilowatts. The maximum demand is measured by a demand meter or may be obtained with the aid of a graphic meter.

Another factor dealing with the economical use of power is the connected-load factor. The connected-load factor of a plant or system is the ratio of the average power consumed to the connected load of the plant or system. The nearer these quantities are to each other, the more economical is the operation of the plant from the power standpoint. If the sum of the ratings of all of the motors in a plant is equal to 1,000 kw., and the average load drawn by these motors is 500 kw., the load factor is equal to 500÷1,000=50 per cent.

While the power charges are not usually based on the connected load, still the fact remains that there is an extra 500 kw. of motor capacity available, which is not used and which at one time represented a capital expenditure. It is practically impossible, in a plant having from 50 to 100 motors, to work all the motors to their full capacities every day of the year, but for economy the connected-load factor of the average plant should be almost as high as the load factor. The connected-load factor is also known as the capacity factor.

Three other factors that are of help in determining whether the power consumed and the equipment consuming it are economically used, are the demand factor, the plant factor, and the diversity factor.

The demand factor of a plant or system is the ratio of the maximum demand or highest peak for a predetermined interval to the total connected load of the plant or system. The demand factor of a small plant utilizing one or two motors that are overloaded will be high. The writer has found instances of load factors as high as 125 per cent. On the other hand, where there is a considerable number of motors, the demand factor may not be higher than 70 per cent. In the average industrial plant, a demand factor of from 85 to 95 per cent is considered good. The value of the demand factor in a load survey is to determine whether the generating and transforming equipment are out of proportion to the total connected load. If the yearly demand factor is 80 per cent of the total rating of the motors, the generating and transforming equipment need not be greater than 80 per cent of the total rating of the motors.

The plant factor of a plant or system is the ratio of the average power consumed to the rated capacity of

the generators, transformers, etc., and is usually slightly lower than the load factor and sometimes equal to the connected-load factor. Its value in a load survey is a further check on demand and other factors.

The diversity factor of a plant or system is the ratio of the sum of the maximum demands of individual loads to the maximum demand of the entire group. Most industrial plants are split up into manufacturing departments, and when all of these various department loads occur at the same time, the diversity factor is unity or 100 per cent. Where the various department peak loads occur at the same time, it is often possible to change the operation so as to stagger the peaks and thus make a more even load and reduce the capacity needed in the generating and transforming equipment. Hence, it is seen that a diversity factor of 100 per cent represents the worst possible condition.

Methods and Instruments Used in Making a Load Survey

From the foregoing it can be seen that in making a load survey it is necessary to determine the connected load, average load, power factor, maximum demand and any abnormal mechanical or electrical losses that may exist. The connected load is, of course, the sum of the ratings of all motors or other energy-consuming apparatus connected to the system. The average load may be measured with a wattmeter, or a graphic wattmeter as shown in Fig. 2.

Power factor may be measured by means of a power factor meter, two wattmeters, or by a wattmeter, ammeter, and voltmeter. Thus, we see that in the last analysis we need instruments to measure watts, volts, and amperes. From the data taken by these measurements we can arrive at the factors and values mentioned previously.

There are several methods of making a load survey, each method depending on the instruments at hand

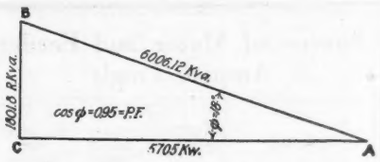


Fig. 5. Relations existing between kva., kw., reactive kva., and power factor.

AB represents the kva. and *AC* the kw. or power component of the load while *BC* is the reactive kva., or wattless component of the load. Power factor is represented by the cosine of the angle between *AC* and *AB*, which is equal to *AC* divided by *AB*.

and the quality of the test. For an elaborate test, two portable graphic wattmeters may be used, one of which has its potential coils connected so that the current and potential of that meter are in quadrature to each other. This method gives very accurate results. The connections for such a test are shown in Fig. 3. Also two switchboard graphic wattmeters connected in this manner are shown in Fig. 2. One wattmeter gives the total kilowatts consumed and shows also the peak at any instant. The remaining wattmeter registers the reactive component of the load. The power factor of the entire system, individual motor, or department group of motors, is then found through the use of the formulas:

$W_1 \div W_2 = \tan a$ and

Cos a=power factor,

In which W_2=reading of wattmeter giving the power component, and

W_1=reading of wattmeter giving reactive component; that is, its current and potential coils are connected in quadrature.

In this formula, a=angle of lag or lead between W_2 and W_1.

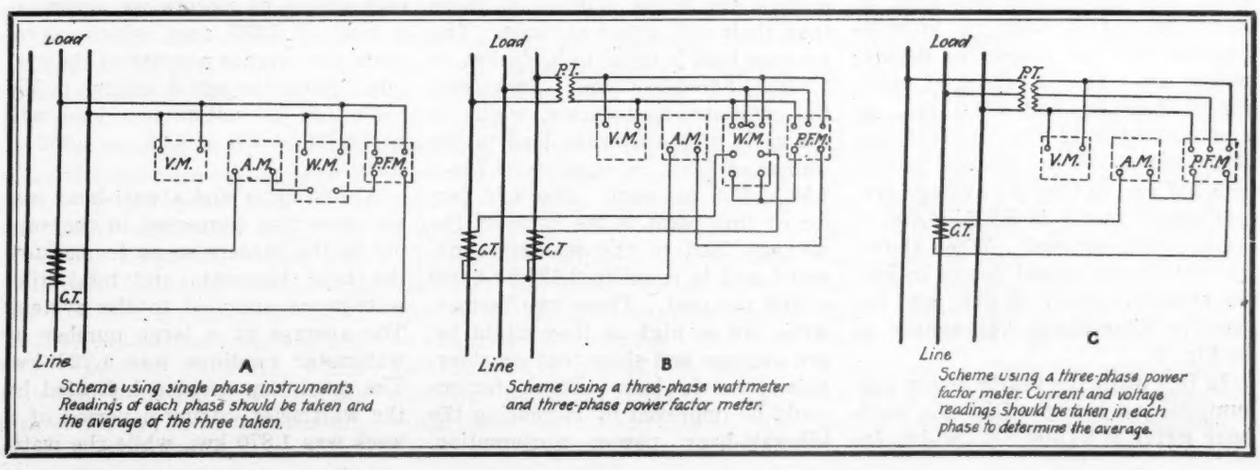
In other words, the reactive component reading divided by the energy reading equals the tangent of the angle of lag or lead between these two components. The cosine of this angle is the power factor of the load under test.

For instance, suppose the reading of the wattmeter W_2 equals 4,800 kw., while the reading of the wattmeter showing the reactive component, or the R. Kva. meter is 2,400 kva. The ratio, 2,400÷4,800=0.5, which is the tangent of the angle. The angle in this case is 26.6 deg., and the cosine of 26.6 deg. is 0.89, which makes the power factor equal to 89 per cent lagging.

Another method of conducting a survey is by means of a wattmeter, an ammeter, a voltmeter, and a power factor meter. The hook-up is as shown in *A* or *B* of Fig. 6. This will give practically the same results as the previous test and if the instruments are of the graphic type, a permanent record is obtained. It is not necessary to have a permanent record, however, and since ordinary measuring instruments are less expensive than graphic instruments they are more widely used. With this arrangement, the instantaneous readings of the meters are taken and the power factor is checked against the reading of the power factor meter from the readings of the other three instruments, by the use of the following formulas:

For single-phase circuits, Power factor=kw.÷kva., or kw.÷(volts×amp.×1,000). For two-phase circuits, Power factor=kw.÷(volts×amp.×1.41×1000).

Fig. 6. Connection schemes for measuring volts, amperes, watts and power factor on three-phase circuits.



For three-phase circuits, Power factor=kw.÷(volts × amp. × 1.73 × 1,000).

A power factor meter is not essential unless it is desired for checking the accuracy of the results obtained from the readings of the other instruments.

Another method involves the use of an ammeter, a voltmeter and a power factor meter, as shown in *C* of Fig. 6. Although this method does not check the kilowatt consumption, if the meters used are accurate the kilowatts can be found from the following formulas:

For single-phase circuits, Kw.=(volts×amp.×power factor)÷1,000.

For two-phase circuits, Kw.=(volts×amp.×power factor×2)÷1,000.

For three-phase circuits, Kw.=(volts×amp.×power factor×1.73)÷1,000.

Some of the meters used in making these tests are shown in Figs. 2 and 4.

Data Obtained From Load Survey of an Industrial Plant

To get a better understanding of the usefulness of a load survey let us consider the case of an industrial plant having a connected load of 7,500 hp., made up of miscellaneous induction and synchronous motors of various sizes and speeds. These motors are grouped under five departments, each department supplied from a separate panel or group of panels, each panel being equipped with a circuit breaker and an ammeter. A check of the various department loads shows ratings of 1,500, 2,000, 900, 2,500 and 600 hp., respectively. This gives a total of 7,500 hp. The average amperes, as shown by the panel ammeters, corresponding to the above loads in their respective order are 1,200, 1,500, 800, 2,200, and 500 amp. at 550 volts. The loads in kilovolt-amperes for the respective departments are then 1,143.12, 1,428.9, 762.08, 2,195.72, and 476.3 kva., or a total of 6,006.12 kva. A totalizing wattmeter shows the average load to be 5,705 kw., so that the average system power factor is 5,705÷6,006.12 =0.95 or 95 per cent. When shown by vectors, the actual power in kw., the apparent power in kva., and the reactive kilovolt-amperes appear as in Fig. 5.

In this plant the yearly power consumption as measured by the watt-hour meter is 31,000,000 kw.-hr. Inasmuch as there are 8,760 hr. in a year, 31,000,000 ÷ 8,760 = 3,538.8 average kw.-hr. per hour, or the average kilowatt load. The maximum demand for the year as shown by the power company's demand meter is 6,000 kw. or 8,040 hp.

Survey of Motor and Feeder Ampere Loads

DRIVE	Rating HP.	Average Load Amp.	Av. Load of Group Amp.
Lineshafting	800	800	800*
Lineshafting	800	750	750†
Lineshafting	250	265	265‡
Elevator Legs	100	110	
Elevator Legs	100	90	375
Elevator Legs	100	95	
Elevator Legs	100	80	
Belt Conveyors	40	45	
Belt Conveyors	40	50	
Belt Conveyors	40	30	
Belt Conveyors	40	45	
Belt Conveyors	40	35	
Belt Conveyors	40	35	300
Belt Conveyors	15	10	
Belt Conveyors	15	9	
Belt Conveyors	15	11	
Belt Conveyors	15	8	
Belt Conveyors	15	12	
Belt Conveyors	15	10	
Cleaner	10	7	
Cleaner	10	7	
Cleaner	10	7	
Cleaner	10	7	
Cleaner	10	7	70
Cleaner	10	7	
Cleaner	10	7	
Cleaner	10	7	
Cleaner	10	7	
Cleaner	10	7	
Miscellaneous	25	22	
Miscellaneous	25	26	
Miscellaneous	5	3	
Miscellaneous	5	3.5	
Miscellaneous	5	4	75
Miscellaneous	10	12	
Miscellaneous	10	12	
Miscellaneous	7.5	6	
Miscellaneous	7.5	7	
Miscellaneous	20	15	
Totals	2,800	.....	2,635

*Friction load =265 amp.
†Friction load =185 amp.
‡Friction load = 80 amp.

The following factors show the condition of the load. The power factor of 95 per cent lagging is exceedingly high. The demand factor, which is equal to the maximum demand divided by the connected load, or 8,040÷7,500=107.2 per cent, is exceedingly high and shows that the motors are being utilized at more than their full rating at times. The average load is equal to 3,538 kw. or 3,538×1.34=4,740 hp. Therefore, the connected-load factor, which is the ratio of the average load to the connected load, is equal to 4,740÷7,500=63.2 per cent. The load factor of this plant is the ratio of the average load to the maximum demand and is equal to 3,538.8÷6,000 =58.8 per cent. These two factors, while not so high as they might be, are average and show that considerable time is lost. These factors could be improved by increasing the kilowatt-hour power consumption, which would also mean increased production.

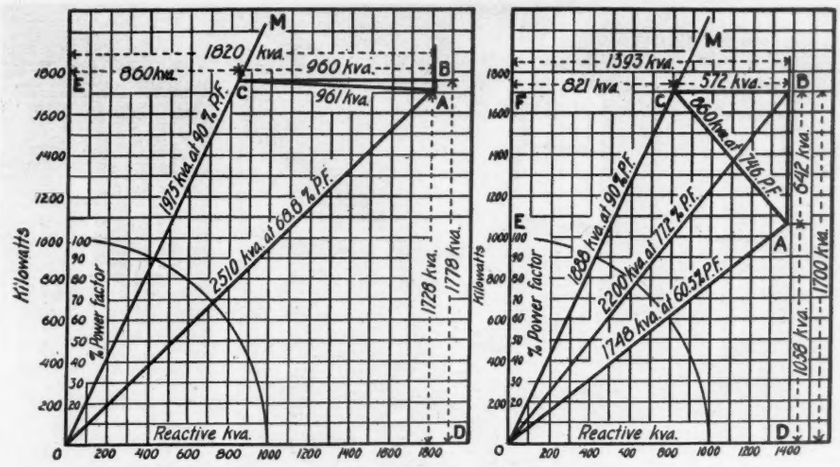
Let us consider another industrial plant that has a connected load of 2,800 hp., the load having been built up by various stages with no record kept of the characteristics of the load. The motors are supplied from two 600-volt, 1,000-kva., three-phase alternators located in the plant and driven by steam engines. It is found that the generators heat up to such an extent with all the motors operating that it is deemed necessary to install an additional alternator.

From a survey of the load conditions in the plant, the data shown in the accompanying table were developed. As can be seen from the table, power was distributed through seven feeder panels to motors which were served in the groups indicated in the table. On the three largest motors, the average load and friction load were measured by means of the ammeters on the feeder panels. In the case of the remaining motors the load on the individual motors was determined by connecting an ammeter at the motor as shown in Fig. 1, while the average load of the group was determined by the ammeters on the feeder panels.

In each case the load current of the individual motors was compared with the nameplate rating of the motor. Comparison of the friction load currents of the two 800-hp. motors disclosed that one was over 40 per cent larger than the other. Investigation showed that this was due to poor alignment of lineshafting and faulty bearings.

The average load of the miscellaneous group of motors is low in comparison with the capacity of the group of motors connected to this feeder panel, because all of them are not operating at the same time. Summing up the average current of each group of motors we arrive at a total of 2,635 amp. which represents the average current of the system. Since the motor voltage is 550 volts, the kilovolt-ampere load will be (2,635 × 550 × 1.73) ÷ 1,000 = 2,510 kva.

A wattmeter and a watt-hour meter were also connected in the supply to the feeders so as to measure the total kilowatts and total kilowatt-hours supplied to the system. The average of a large number of wattmeter readings was 1,728 kw. The maximum demand indicated by the wattmeter during a period of a week was 1,870 kw., while the watt-



Figs. 7 and 8. Graphs that show how replacing a wound-rotor induction motor with a synchronous motor eliminated the need of more generator capacity.

In Fig. 7, *AO* represents the original load kva. at 70.7 per cent power factor. *CO* represents the result of using a synchronous condenser to raise the power factor to 90 per cent. After eliminating one of the wound-rotor motors, the load condition was as shown at *AO* of Fig. 8. This motor was replaced with a synchronous motor of capacity equal to *CA*. It pulled a power load of *AB* and supplied reactive kva. of leading power factor equal to *BC*, which resulted in the system load shown at *CO*.

hour meter showed a consumption of 225,965 kw.-hr. Assuming this to be an average week, the yearly energy consumption would be 52×225,965=11,750,180 kw-hr. These data were then put in the form of the accompanying report:

(1) Total annual power consumption —11,750,180 kw.-hr.
(2) Total number hours per day—8,760.
(3) Average kilowatt-hour consumption equals Item (1) divided by Item (2) equals 1,341 kw.-hr. per hr.
(4) Maximum demand—1,870 kw.
(5) Generator capacity—2,000 kw.
(6) Connected load—2,800 hp. or 2,089 kw.
(7) Average kilowatt load—1,728 kw.
(8) Average kilovolt-ampere load—2,510 kva.

Power factor equals Item (7) divided by Item (8) equals 68.8 per cent.

Load factor equals Item (3) divided by Item (4) equals 71.7 per cent.

Connected-load factor equals Item (3) divided by Item (6) equals 64.3 per cent.

Plant factor equals Item (3) divided by Item (5) equals 67 per cent.

Demand factor equals Item (4) divided by Item (6) equals 89.5 per cent.

The above report shows that with the exception of the power factor, which was exceedingly low, the various factors were a good average. It was recommended that the power factor of the system be raised to at least 90 per cent lagging so as to bring the kilovolt-ampere load within the rating of the generator. Three methods of doing this were presented.

The first method was to install static condensers; the second was to install a synchronous motor for power factor correction only; the third was to scrap one of the 800-hp. slip-ring induction motors and replace it with a synchronous motor.

The first two methods were turned down in favor of the third, which was thought to be the best. Details of the second and third methods are shown in Figs. 7 and 8.

Fig. 7 shows the original load conditions of 2,510 kva. at 68.8 per cent power factor, as represented by the line *AO*. The true power component of 1,728 kw. is represented by the distance *AD* and the reactive component of 1,820 kva. by the distance *BE*.

The smallest synchronous condenser that would raise the power factor from 68.8 to 90 per cent is shown by the line *AC*, which represents 961 kva. This condenser when operated at approximately zero leading power factor would supply a leading reactive component of 960 kva. *AB* represents the losses in the condenser which amount to 50 kw.

This would increase the true power to 1,778 kw. and would reduce the total kilovolt-amperes required by the system from 2,510 to 1,975 kva. thereby just getting within the 2,000-kva. rating of the generators. However, it would mean adding a 961- or 1,000-kva. condenser to the system.

Instead of using a synchronous condenser for power factor correction the synchronous machine might be run as an over-excited motor and substituted for one of the 800-hp. slip-ring induction motors. This would give us the benefit of the higher efficiency of the synchronous motor (93 per cent as compared with 89 per cent for the induction motor) as well as not increasing the number of motors that would have to be maintained. This plan was adopted and the resulting conditions are shown in Fig. 8.

Since the 800-hp. slip-ring induction motors have an efficiency of 89 per cent, removing one of them reduced the load by (800×746)÷(0.89×1,000)=670 kw. Therefore the remaining load is 1,728 kw.—670 kw.=1,058 kw., or *AD* in Fig. 8. The kilovolt-ampere load of the slip-ring induction motor as determined by test was (800×550×1.732)÷1,000=762 kva. Hence in removing this motor the total kilovolt-ampere load would be reduced, 2,510—762=1,748 kva. as is represented by *AO* in Fig. 8. This load has a power factor of 60.5 per cent, for 1,058÷1,748=0.605, or 60.5 per cent.

The efficiency of a synchronous motor is somewhat higher than that of a slip-ring motor and for practical purposes may be figured as 93 per cent. Hence if a synchronous motor is substituted for the 800-hp., slip-ring motor, the kilowatt input to the synchronous motor will be (800×746)÷(0.93×1,000)=642 kw. This added to the 1,058 kw. load remaining gives a total of 1,700 kw. which is the total kilowatt or true power required if a synchronous motor is substituted for the slip-ring induction motor. In Fig. 8 *AD* represents the kilowatt load after removing the slip-ring motor; *AB* is the kilowatt input to the synchronous motor; and *BD* is the total kilowatt input or true power required by the system. The distance *AE* in Fig. 8 represents the reactive kilovolt-amperes taken by the 1,748-kva. load at 60.5 per cent power factor. This is equal to 1,393 kva. *BF* is drawn at right angles to *AB* from point *B* and also represents the reactive kilovolt-amperes shown at *AE*.

If the synchronous motor were operated at unity power factor, its capacity would only need be large enough to take care of the 642-kw. load represented by *AB*. In this case the total plant kilovolt-ampere load would be equal to *BO*. Scaling this and checking it against the power factor scale we find that *BO* equals 2,200 kva. at 77.2 per cent power factor. Since the generators are rated at 2,000 kva. it is necessary to over-excite the synchronous

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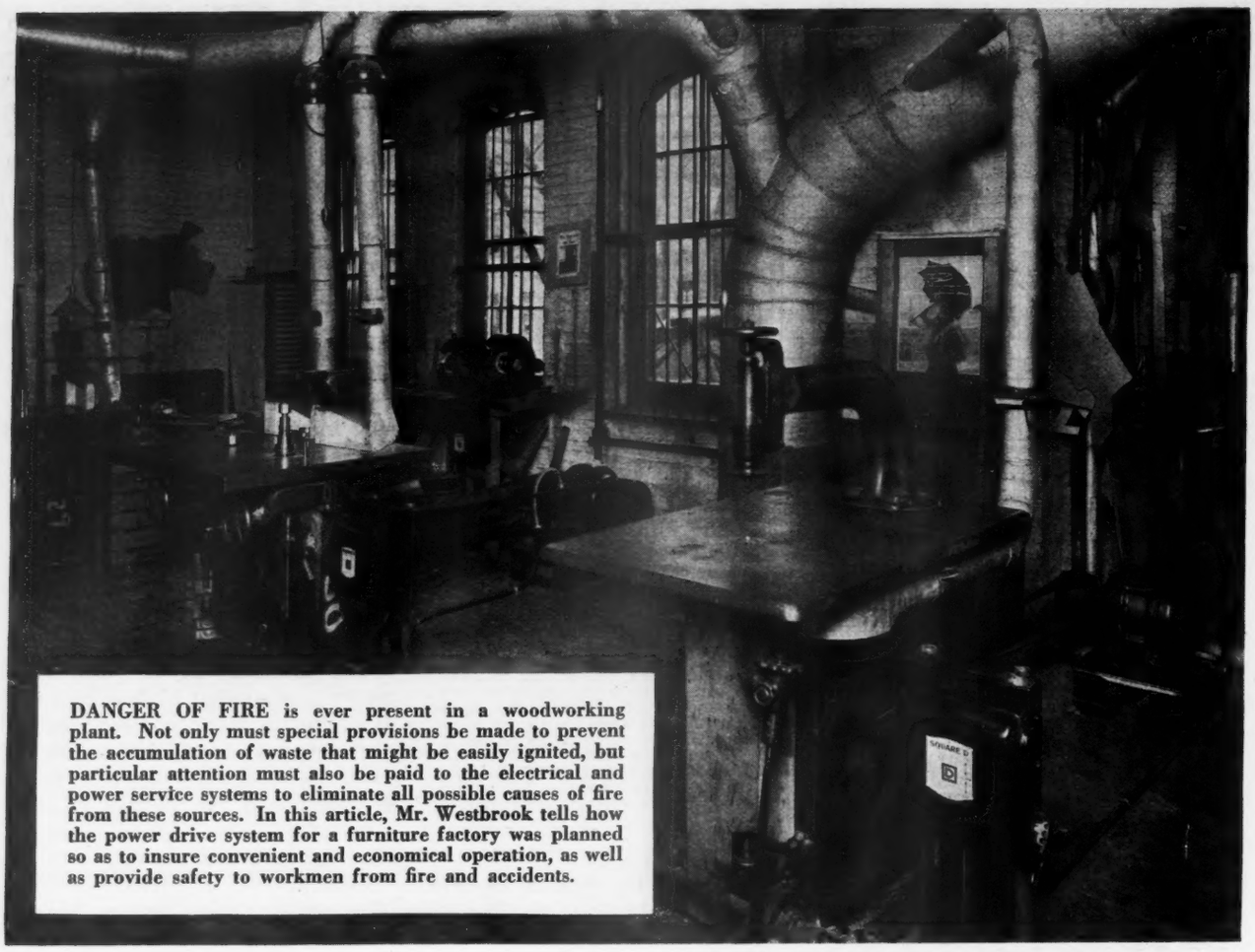


DANGER OF FIRE is ever present in a woodworking plant. Not only must special provisions be made to prevent the accumulation of waste that might be easily ignited, but particular attention must also be paid to the electrical and power service systems to eliminate all possible causes of fire from these sources. In this article, Mr. Westbrook tells how the power drive system for a furniture factory was planned so as to insure convenient and economical operation, as well as provide safety to workmen from fire and accidents.

Fig. 1—Convenient location of the control switch is an important factor in any motor installation.
In the center is a double variety machine or molder. The motor used for driving this machine has the shaft extended on both ends, which is fitted with two pulleys so as to drive each spindle with a separate belt. At the left and at the right are single variety machines. In the center background is a grinder. Note that in each installation the control switch is within convenient reach of the right hand of the operator as he stands at his work.

Some Practical Details of the

Power Service Layout For a Woodworking Plant

Including the Features of the Electrical Distribution System, Together with the Types of Motors, Control and Drives That Were Used

By FRANCIS A. WESTBROOK

Consulting Engineer, New Canaan, Conn.

IN A woodworking plant the great danger is the fire hazard. For this reason the use of the proper kind of motor and a carefully installed wiring system are of prime importance. The principles governing the method of meeting this condition in a woodworking plant are, of course, applicable in many other cases where a dangerous fire hazard exists. Special consideration was given this factor in planning the electrical distribution and power drive system for the new factory of Albano & Company, of New York City, manufacturers of high-grade furniture. The practice of placing all wires in conduit, even to the extent of using flexible conduit for motor leads, was followed throughout this plant. This feature and the use of enclosed-type, safety, motor disconnecting switches and squirrel-cage induction motors have reduced the fire risk from electrical causes to a minimum—one might almost say they eliminated it.

In a plant of this kind variable-speed motors are not required. Consequently, squirrel-cage motors may be used throughout and in this instance they are all 1,800 r.p.m. There are, in all 35 motors of various sizes as shown in the accompanying table. All are designed for 220-volt, three-phase, 60-cycle service.

The kind of building in which a power distribution system for such a group of motors is installed has more to do with the methods of installing conduits and panel boxes than is perhaps generally recognized. In this case, the new home of Albano & Company is a very substantial brick building but of an old

type with wood floors, except the ground floor, which is concrete. There are five floors. The first (ground floor) and third are used for woodworking machinery, the second for storage and the fourth and fifth for upholstering and other hand work.

Under these conditions, the simplest method of installing conduit is to mount the panel box in a central location on the floor below that where the machines to be served are located. The conduits are then run on the ceiling of this lower floor from the panel box to a point directly under the control apparatus they are to supply with power, and pass up through the floor. Although it may at first thought appear that it would be inconvenient to have to run downstairs to replace fuses, this contingency should occur so rarely in a properly planned distribution system with conductors of adequate capacity, that it would not control the location of the panel boxes. Moreover, the fuses most likely to blow are those located at the motor starting switch and in each case these are located at the machine. The panel boxes and feeder lines for machines on the first (ground) and third floors are located in the basement and on the second floor respectively.

Obviously this method of installation is very simple, convenient and economical for these conditions, but it would be unsatisfactory if the floors were wet, especially if they were of wood, as in a laundry. In fact, ordinary wood floors would be out of the question in a laundry, but there are other processes which result in wet floors where moisture gets into the conduits and causes trouble in cases where the latter has been installed in this way.

Size and Number of Motors with Method of Drive Used in Woodworking Plant*

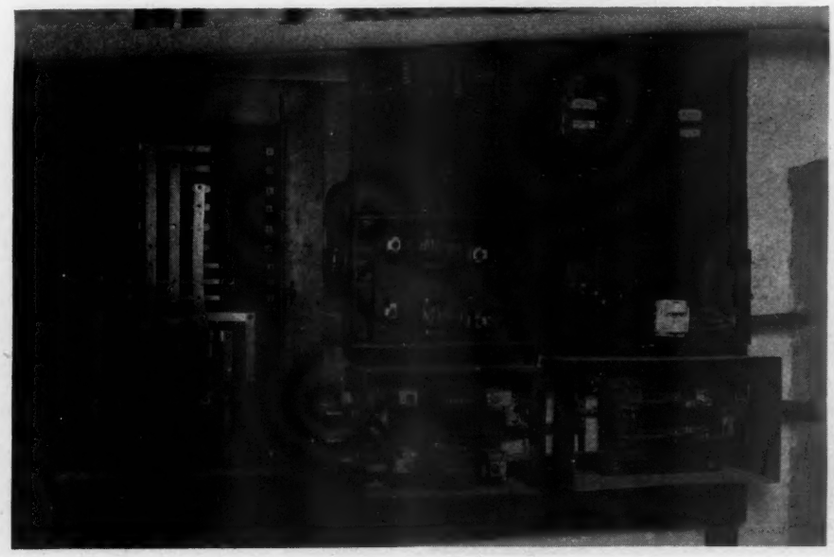
Name of Machine	Location, Floor	No. of Motors	Hp. of Motor	R.P.M.	Control	Drive
Blower for exhaust system	2	1	30	1,800	Compensator	Belt
Buss planer	1	1	10	1,800	Compensator	Direct
Jig saw	3	1	1.5	1,800	Starting Switch	Belt
Saw tables	1	6	3	1,800	Starting Switch	Belt
Horizontal borer	3	2	2.5	1,800	Starting Switch	Belt
Vertical borer	3	1	2.5	1,800	Starting Switch	Belt
Swing saws	3	3	3	1,800	Starting Switch	Direct
Band saws	1	2	3	1,800	Starting Switch	Belt
Double variety machine	3	1	7	1,800	Compensator	Belt
Single variety machine	3	1	5	1,800	Starting Switch	Belt
Dovetailer	3	1	3	1,800	Starting Switch	Belt
Carvers	3	3	3	1,800	Starting Switch	Belt
Single variety machine	3	1	3	1,800	Starting Switch	Belt
Fan for drying room	3	1	3	1,800	Starting Switch	Belt
Box shaper	3	1	3	1,800	Starting Switch	Belt
Jointers	1	3	3	1,800	Starting Switch.	Belt
Lathes	3	2	1.5	1,800	Starting Switch	Belt
Emery grinder	3	1	1.5	1,800	Starting Switch	Direct
Belt sander	3	2	2	1,800	Starting Switch	Belt
Rip saw	3	1	2	1,800	Starting Switch	Direct

*All of the motors listed here are squirrel-cage type.

Three-phase, 60-cycle, 220-volt power is delivered to the service entrance in the basement as shown in Fig. 2. As can be seen at the lower right of this illustration, the power goes through a disconnecting switch, and then through two 500-amp. current transformers (for metering) to the power panel shown at the left of Fig. 2. At the bottom of this panel is the 600-amp. service switch. Through the three 400-amp. fuses at the bottom of this panel, power is taken to two distribution panels, one in the basement and one on the second floor.

Fig. 2—Power service is brought into the basement of the building at this point.

The lower cable at the right furnishes the 220-volt, three-phase power supply, while the cable above it is the lighting supply. The circuits are carried to the left through the current transformers (for the two meters above), after which the power circuit goes to the main power panel shown at the left. The lighting current is fed directly from the current transformers to the lighting panels on the different floors. From the main power panel shown at the left, power is fed through the 100-amp. fuse gaps at the left center of the panel to the elevator motor. The 400-amp. fuse gaps at the bottom of the panel supply the two power distribution panels—one of which is located in the basement and the other on the second floor.



The power distribution panels are of the polarized type. The panel in the basement has a capacity of 12 circuits with eight 30-amp. and four 60-amp. gaps. Cables enter it from the main power panel, shown in Fig. 2, in two 2-in. conduits and there are three 1-in. and one ¾-in. conduits leaving it for distribution to the 12 machines on the floor above. The method of delivering the power to the individual motors on the first floor can be seen in Figs. 4 and 6.

The panel box on the third floor is fed through two 2-in. conduits coming from the panel box in the basement, the feeder passing through the latter box. Distribution to the 23 machines on the floor above is through five 1-in., three 1¼-in. and one ½-in. conduits as shown in Fig. 3.

It is evident that, in some instances, there is more than one circuit per conduit leaving the panel boxes. At certain points there are pull boxes from which separate conduits radiate to locations under their respective machines at which point the conduits pass up through the floor. In some cases it was conven-

ient to locate these pull boxes above the floor, as shown in Fig. 5.

Fig. 3 shows the conduit and motor layout for the third floor. Some of the machines on this floor are shown in Figs. 1, 5 and 7.

As has been said before, all of the motors are squirrel-cage induction motors. This simplified the question of control, not only because the motors are small but also because there is no necessity of speed variation. Furthermore, the class of labor which operates the machinery is mechanically skilled and intelligent —a very different condition from that which exists in a laundry, for instance. Reference to the accompanying table will show that compensators are used for controlling all motors larger than 5 hp. A typical compensator installation is shown in Fig. 6. Power is delivered from the distribution panel in the basement to the safety switch mounted above the compensator. This safety switch is used for isolating the motor and compensator from the power supply when doing maintenance or repair work.

For motors smaller than 5 hp. a manually-operated motor starting switch is used. These switches start the motor across the line with the fuses cut out of the circuit. As the motor comes up to normal speed the switch is thrown to the running position, which cuts the fuses back into the circuit. Needless to say, these motor starting switches are of the safety type, being totally enclosed in sheet metal boxes. Typical installations of these starters are shown in Fig. 1. Wherever it was possible and convenient, the safety switches, compensators and motor starting switches were attached to the building columns, as shown in Fig. 4.

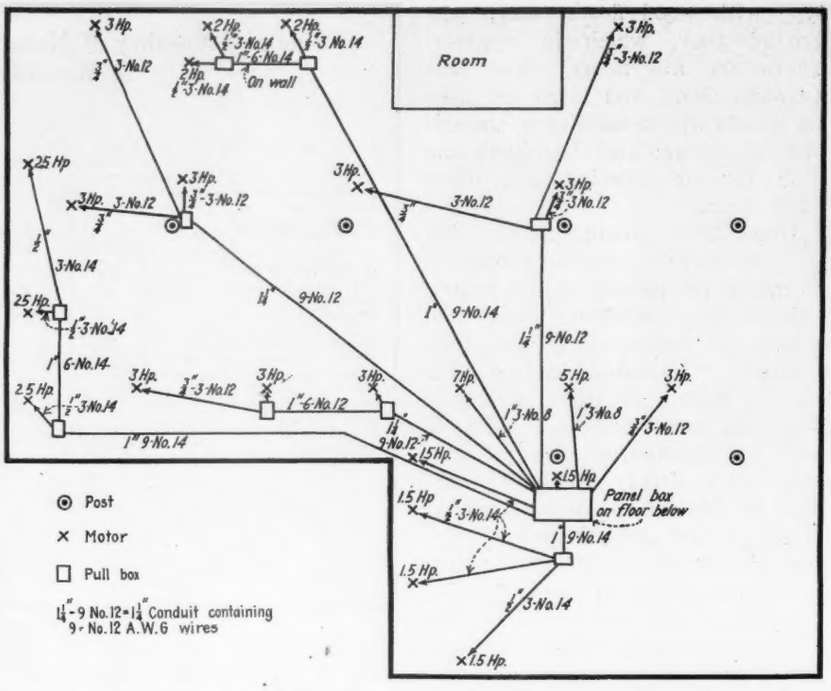


Fig. 3—Motor and conduit layout for the third floor.

A panel box was located on the second floor from which conduit was run on the ceiling of the second floor to points immediately under the locations of the third-floor motors. Conduit was then taken through the floor to the motor directly above it. This made a very simple and economical installation.

Convenience of control was the first consideration in each case, however, so that in many instances the control was mounted on pipe standards convenient to the machine operator's hand, as shown in Fig. 1.

The three swing saws, one rip saw, the emery grinder and the Buss planer are directly connected to the motors. In these instances the motors are mounted on the machines that they drive. All of the other machines are belt driven. The belted motors on the first floor are mounted directly on the concrete floor. Since the upper floors are of wood, the motors on the second and third floors are provided with drip pans under them so as to reduce the fire hazard from oil-soaked wooden floors. The method of installing the drip pans can be seen in Fig. 5. All of the motors were provided with conduit fittings which were connected by means of flexible conduit to the rigid conduit running from the control to

Fig. 4—Belt drives are used in the majority of cases in this shop.

In the right foreground is a jointer with its motor on the floor and control switch on the building column. Note how the motor leads enter the motor casing through flexible Greenfield conduit, so as to avoid all exposed terminals and to make a flexible connection between the rigid conduit and the motor so that it may be shifted on its slide rails in order to tighten the belt. In the left foreground are two saw tables. The control switches are mounted on stanchions. The conduits coming from the panel box in the basement may be seen coming up through the floor. The conduit from the switch to the motor is laid on top of the floor. To the right and at the rear, mounted on a column, will be seen the compensator and switch for the large exhaust fan located on the floor above. As that floor is used for storage purposes only, it saves much running back and forth to have this control apparatus on the ground floor where there are workmen all the time. There is an additional switch at the blower for the protection of men who maintain it.

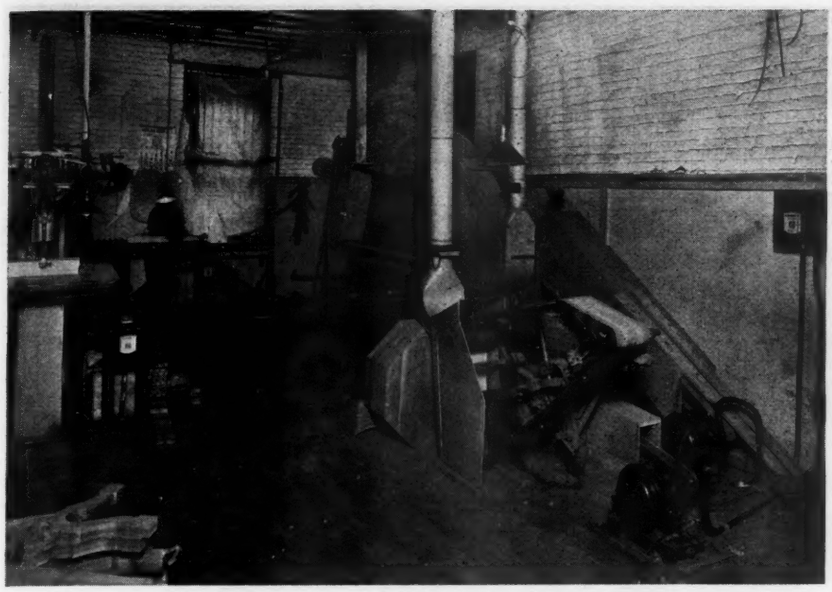


Fig. 5—Provision was made to take care of the wood waste by means of an exhauster system.

At the right are two belt sanders. As can be seen, one end of each is enclosed and connected to an exhaust pipe. Sawdust and other wood waste coming from these machines is sucked to a central depository. In this way much of the dust and dirt that would otherwise get into the motors is removed. On the left is a jigsaw with its control switch mounted on stanchions under the saw table. In the center background is a two-spindle horizontal drill with its control switch and motor. Notice how the motor belt on this drive, as well as those on the two belt sanders, is enclosed. At the extreme right between the floor and control switch of one of the belt sanders is one of the pull boxes shown in Fig. 3. Notice the drip pans placed under the belt sander motors to keep oil off the floor.

a point near the motor, as shown in Figs. 4 and 5. This method of installation not only avoided all exposed terminals and wires but also provided a flexible connection between the motors and rigid conduit so that the motor can easily be moved on its slide rails.

All belts and every other moving part, in so far as possible, are completely enclosed, thereby reducing the liability of accidents. These enclosures are boxes which may be readily disassembled for repair and maintenance work. As the foreman said, almost all of the old woodworkers have missing fingers or parts of fingers, but all of the young men are without these disfigurements, because of the great and effective precautions which are taken against accidents in modern plants. In fact, no accidents of any consequence have occurred since these enclosing guards were installed.

The exhaust system for carrying off sawdust and accumulations of dirt is very comprehensive, and is an important factor in reducing fire, health and accident hazards. The machines are equipped with hoods or other suction devices, as shown in Figs. 1 and 5. Also there are openings in a large suction pipe on each floor into which sweepings may be pushed without the necessity of carrying them away. One of these may be seen in Fig. 7. This is also of decided benefit from the standpoint of motor maintenance, as it reduces the amount of foreign material that might get into the motors.

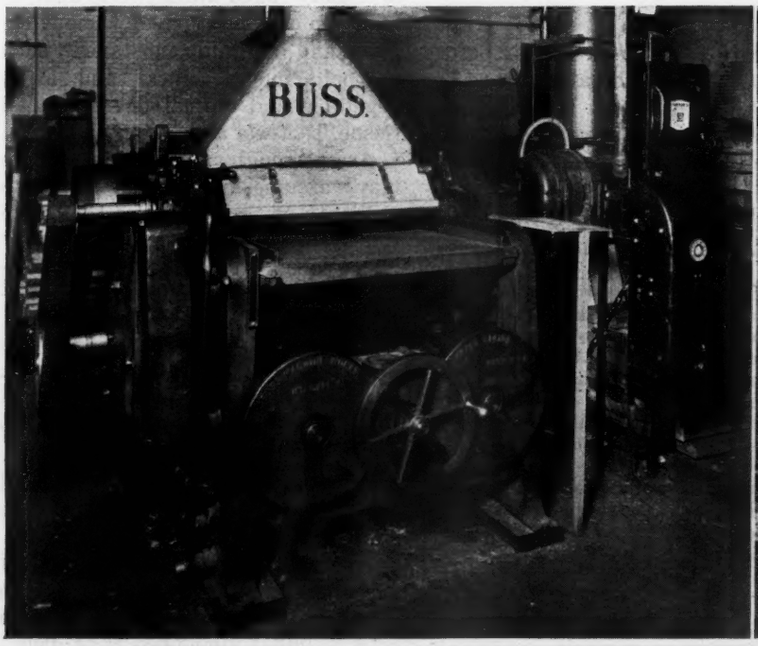
EDITOR'S NOTE: Special acknowledgment is made to MacNutt, Watts and Tankard, Electrical Engineers and Contractors, New York, N. Y., for the illustrations used in this article.

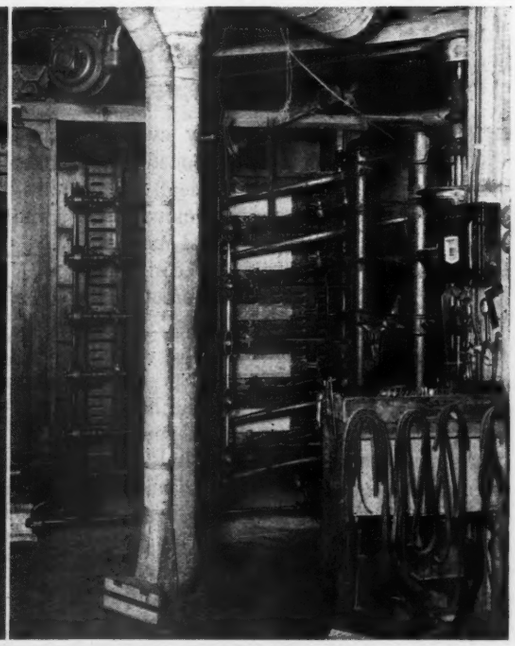
Fig. 6—Motor and control arrangement for Buss planer drive.

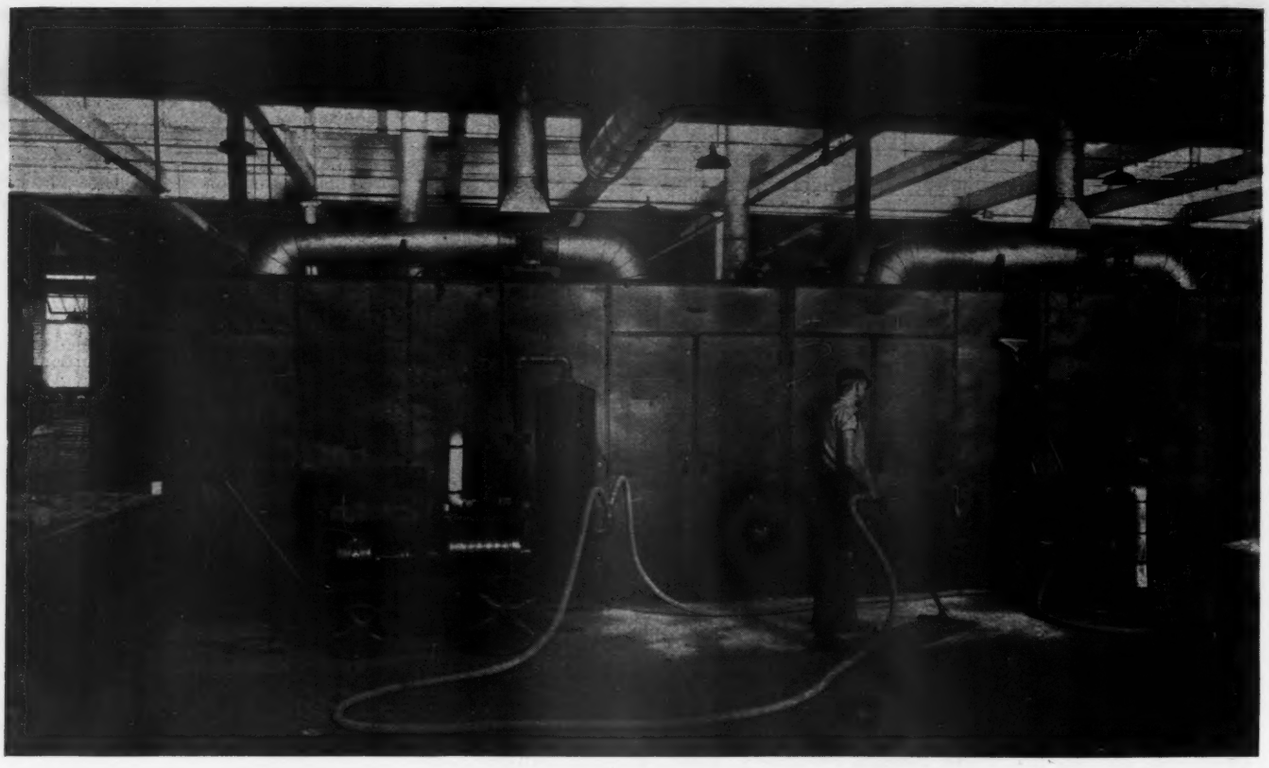
The belt on the left operates the feed mechanism; the motor is coupled directly to the machine. Normally, all belts and other moving parts are completely boxed in. This protection was temporarily removed while the pictures were being taken. The compensator, with push button stop, and enclosed-type disconnecting switch are shown to the right of the machine, in a convenient location for the operator.

Fig. 7—Floor space requirements caused the motor driving this machine to be mounted on the ceiling.

This machine has a vertical drive shaft and as it covers considerable floor space which must be free for the operator to walk around in, the best place for the motor is on the ceiling where it, with its belt, is out of the way. The vertical shaft in the foreground at the right is driven by a twisted belt from the motor at the left. From this vertical shaft smaller belts go directly to each carving tool on the machine.







Here industrial sweeping units are used to clean up the floor and the side walls. Solid material is separated in the cylindrical tank and does not go through the multi-stage exhauster driven by the motor.

Some Things It Pays To Know About

Removing Dust Produced in Industrial Plants

Including Equipment and Methods Used, With a Discussion of the Effects of Dust on Men and Machines and Its Relation to Fire Hazards

By CHARLES L. HUBBARD

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DUST exists practically everywhere and is produced to some extent in practically all industrial processes. Its removal is accomplished by methods and means similar to those described in connection with the article, "Removing Obnoxious Fumes, Gases and Vapors," which appeared in the June issue of INDUSTRIAL ENGINEER.

The fact that dust, even the heavier particles, will remain suspended for a time in the air is employed in removing it on the same principles as are used in removing gases, fumes and vapors. With the heavier dust, however, the problem of keeping it suspended is more difficult. Also it is generally desirable to remove the dust from the air before discharging into the atmosphere.

Dust is produced in an almost endless variety of ways and is often spoken of as man's worst enemy. It causes sickness and death, is responsible for fires and explosions, injures machinery and manufactured products, damages both interior and exterior surfaces and, in the aggregate, causes the loss of millions of dollars annually.

DUST REMOVAL problems in industrial plants are, like those connected with the removal of gases, fumes and vapors, solved by carrying the objectionable material along on a current of air. Some of the hazards, as well as the inconveniences, of atmospheric and industrial dust are taken up here, together with the equipment for handling it. Methods of removing the dust from the air current before discharging it into the atmosphere will be discussed in an article in a later issue.

There are many different kinds of dust, coming from the mineral, vegetable and animal kingdoms. That contained in the outside air, which is usually called atmospheric dust, is made up of a mixture of various organic and inorganic substances, such as coal, cinders, ashes, sand, loam, vegetable and animal fibers, animal tissue, bacteria and so on.

As a rough approximation, we may assume that one hundred-millionth of the volume of the air in the vicinity of the average power house consists of dust and other foreign particles. While this proportion of dust may seem negligible, and is, in fact, not so great as is often found, it means that the ventilating air passed through a large generator in 24 hr. will contain nearly 1 cu. ft. of solid matter. Some of this, if left in the air, would naturally be deposited upon the winding and later cause trouble.

Another interesting example of the amount of dust in the air is in connection with the air brought in

for the ventilation of a large city school building where the outside conditions were such as to indicate an average atmospheric purity much above that which would ordinarily be found around industrial plants. Tests by means of an air filter showed that 50 lb. of dry dust were brought in with the air during each 6-hr. session of the school day. If this 50 lb. or more of dust is taken into the schoolroom or plant daily much of it is deposited on floors, walls, ceilings and on the top of equipment or projecting ledges. Some of the dust, of course, is carried out again as the air leaves the room or plant; that which remains must be cleaned up or removed periodically. The expense of this cleaning is of considerable importance.

That portion of the dust which settles on lighting units and any white walls or ceilings materially reduces the illumination of the plant. To overcome this requires periodic cleaning of lighting units and reflectors and repainting of surfaces. In addition to the dust ordinarily found in the atmosphere and which may be brought into the plant through an unprotected ventilating system, many industrial processes create dust. It is produced in an endless variety of ways, as in grinding and polishing, stone cutting, sandblasting operations, shoe manufacturing, woodworking, cleaning castings in foundries, the operation of pickers in textile mills and in many other operations or processes. Dust is also produced in great quantities in the manufacture of flour, sugar, starch, cement and in the crushing or handling of coal and other products. The lint of textile mills is also a form of dust which must be contended with.

Some of the Effects of Dust in Industry

While many kinds of dust found in the air are practically harmless in themselves, they serve as a means of transmission for various germs. Therefore, the first, and most important, step in the elimination of disease germs from an industrial establishment is that of clearing the air supply of all foreign substances.

The effect of dust upon health depends largely upon local conditions, such as its composition, concentration and the period of exposure. While a moderate amount of dust such as is commonly found in woodworking shops, shoe factories, foundries, and so on, is simply irritating to the respiratory passages, it often tends to bring on inflamed and infected conditions of the nasal passages which make a person especially liable to colds and other acute diseases of this class.

Metallic and mineral dust, which comes from the grinding and polishing of metals, stone cutting, sandblasting, and so on, is more harmful, as continued breathing of air loaded with these substances causes the heavy particles to accumulate in the lungs; "stone-cutters consumption" is a well-known malady among persons engaged in this occupation. Breathing the dust of poisonous substances like lead, is more rapid in its effects and is similar to the inhalation of a poisonous gas.

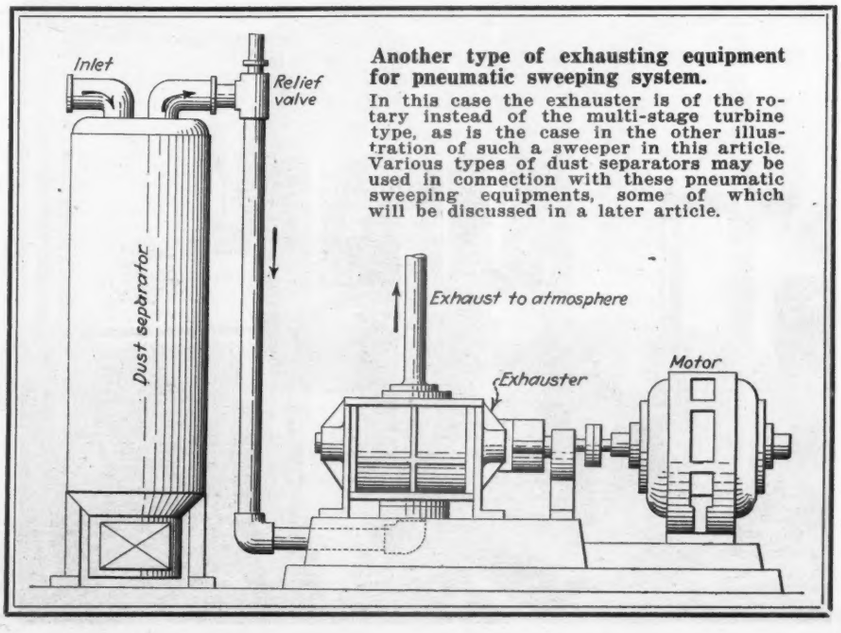
Some dusts are both inflammable and explosive. The fire hazard is increased in textile mills by the accumulation of lint around shafting and bearings. Fires have been traced to hot bearings which ignited the lint or dust around them. Also, if the shaft or bearing is overhead, oil-soaked lint may fall on the work in process and at least seriously depreciate its value if not make it entirely worthless. One of the big problems of textile mills is to remove this lint from the walls and ceilings of the rooms. It is also necessary to clean the lint off the machines themselves at frequent intervals to keep them in running order. Much the same condition occurs in woodworking and other shops where a bulky dust takes the place of lint.

In direct line with this is the danger of explosion where the nature of the process carried on is such as to fill the air with a fine carbonaceous dust, as in connection with the manufacture of wood products, charcoal, celluloid and so on. An example of the great danger which may be brought about in this way is the explosion which occurred in the Chicago and Northwestern grain elevator in Chicago in 1921, where the damage to property and loss of grain was estimated at $3,750,000.

Dust explosions in coal mines are also common. A similar hazard exists in connection with the pulverizing and handling of powdered coal in power plants, cement mills and other industries. The pulverizing of aluminum and hard rubber also create explosive hazards. Starch and flour mills have likewise been destroyed by explosions. About a year and a half ago, 42 men lost their lives in an explosion in a starch factory, which was attributed to a hot bearing in a screw conveyor.

In most industries, however, the explosion hazard is negligible, although some of them, such as woodworking and others have a fire hazard. The more common dust removal problem is in connection with preventing dust from interfering with the machines, in keeping the plant clean and in providing clean air for a process or for the comfort, convenience and health of the workers.

Injury to machinery is produced principally by dust of a gritty nature which enters the bearings. This condition may be brought about by dust produced by the process or



Another type of exhausting equipment for pneumatic sweeping system.
In this case the exhauster is of the rotary instead of the multi-stage turbine type, as is the case in the other illustration of such a sweeper in this article. Various types of dust separators may be used in connection with these pneumatic sweeping equipments, some of which will be discussed in a later article.

Two examples of a sweeping operation in a rubber plant.

These sections of vacuum units are connected to filters and an exhaust sweeping unit similar to that below. Some industrial processes produce a fine dust. If this were swept up by a broom the dust would simply be raised and much of it settle again. By the method shown here, it can be easily removed not only from the floor but from hoods, walls and other places. Vacuum cleaning is practically the only method of sweeping which will not raise a dust. In some industries and plants the sweepings which are gathered up in this way can be worked over again when removed by the filters.

from the use of unfiltered outside air as in the ventilation of generators and transformers. An important matter sometimes overlooked is that of filtering the air supplied to compressors and internal combustion engines, when it contains gritty particles which will score the cylinders.

Damage to goods in process of manufacture may occur in various ways, either from dust produced in the building itself or from that brought in from outside. This is illustrated in plants making fine silk or paper goods, where dust and dirty lint must be kept away from the manufactured product in its different stages. Other cases where dust must be removed from the entering air are in the manufacture and drying of food products, photographic films, prepared papers, chemicals, and so on. As previously stated, bacteria are commonly carried upon particles of dust. These organisms thrive upon gelatin, glue and certain food products, such as butter, milk and cheese, so that dust not only has a direct effect upon the quality when coming in contact with these substances, but may infect them as well.

Methods of Collecting and Removing Dust

The operations of collecting, removing and disposing of both atmospheric and process-created dust are so closely related that they will be discussed together here. The problem of the disposal of dust after it has been collected must be carefully considered, as in many localities the free discharge of dust-laden air, outbound, will prove a nuisance to neighboring buildings and other property and often is not permitted.

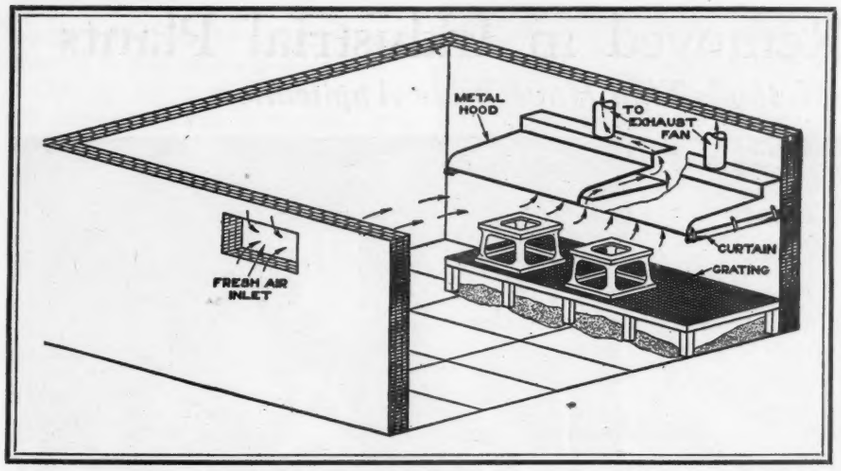
The dust from cement kilns, flour mills, grinding and polishing machinery, sandblasting operations and so on, are illustrations of this. In certain manufacturing plants, it is not only desirable to collect and remove the dust for reasons already mentioned, but also for the purpose of reclaiming various waste substances which it contains. This is notably the case in gold- and silver-working establishments, where all sweepings and refuse from polishing machines must be carefully collected and treated. In other cases the precipitation of dust from heavy fumes or smoke is practiced at a profit. Most types of dust, however, have no value.

The removal of dust may be classed under four general heads, as follows (*a*) Removal as it is produced at the source. (*b*) Removal after mixing with the air of the room. (*c*) Removal after it has settled upon the walls, floor and other objects. (*d*) Removal from outside air supplied to the building and from that exhausted from it.

The methods and equipment for removing dust as it is produced at the source or after it becomes diffused in the room are quite similar to those used for removing fumes, gases and vapors as described in the previous article. The main difference is that because dusts are heavier they require a higher velocity of air

This heavy-duty stationary sweeping system unit was installed in the Cleveland, Ohio, plant of the Willard Storage Battery Co.

The dust and dirt are dumped automatically from the separating tanks Nos. 1 and 2 through chutes to bins located on the floor below. This apparatus is installed on the roof of the building in a special house built for this purpose. For this reason all of the dust and dirt must be drawn upward through vertical pipes such as are shown at the right, which go down to the floors where the sweeping is to be done. Men with hose lines and special sweeping units do the sweeping. Before the dirt passes through the multi-stage turbine exhauster it passes through the two separating tanks or filters.



One type of ventilating arrangement for a sandblasting room.
Here the work to be sandblasted is placed on the grating. A suction through the metal hood above the work draws the dust away from the operator. The hood is open around the edge only to give a higher velocity of the entering air and therefore a greater suction. This method is also used in withdrawing gases and fumes. In some cases a suction is placed under the grating in the bench top also. Fresh air enters from the opposite side of the room.

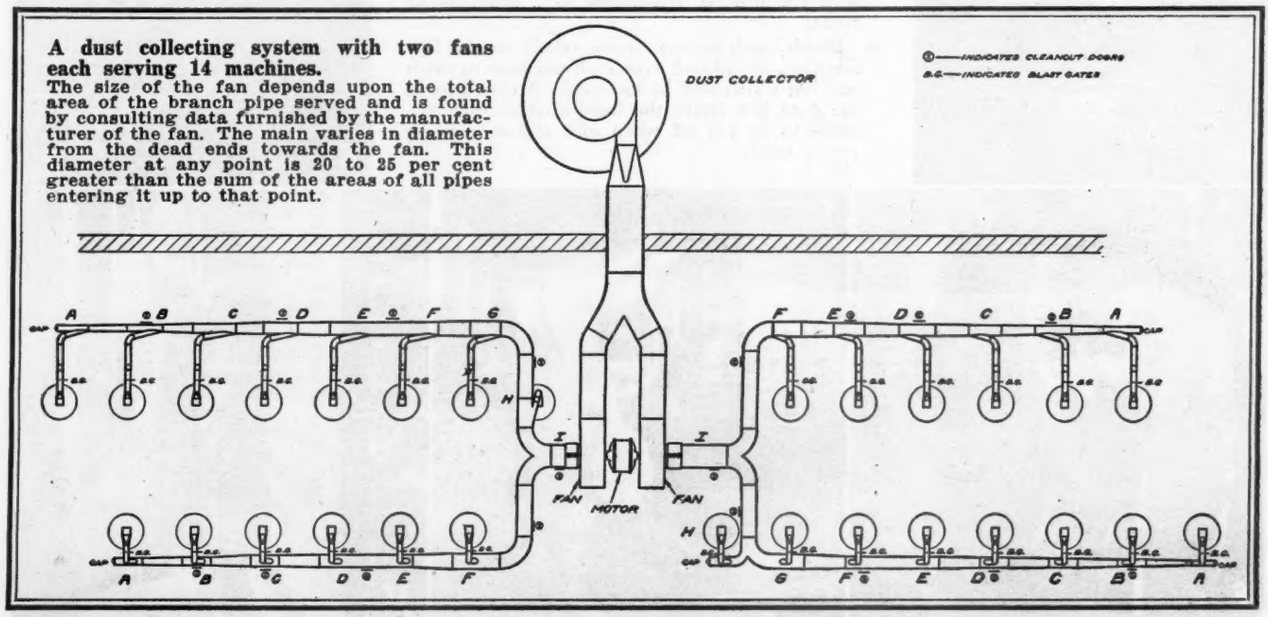
to keep the particles suspended in the air and carry them away. Also, as previously mentioned, it is seldom possible to exhaust dusts into the open. This requires the addition of extra equipment to separate the dust from the air before it is exhausted, which, in turn, increases the head or pressure against which the exhaust fan works and so requires more power to operate than a similar system exhausting the same quantity of air containing fumes or gases directly into the atmosphere.

In the case of grinding and buffing, the wheels are surrounded with a hood, which is connected with the exhaust line and has just enough of the circumference of the casing cut away to reach the wheel easily for the work to be done. Other machines of various kinds are provided with similar hoods for carrying away the dust and fine refuse produced while in operation. The suction required will depend upon the nature of the dust, as to fineness, weight, and so on, and commonly runs from 2 to 5 in. of water column. Some states have factory inspection regulations which specify the suction to be maintained when exhausting different substances. The shape of the hood in all cases depends upon the machine and the requirements of operation. Tables I and II on page 355 give dimensions of exhaust pipes leading off from various machines.

It is desirable to keep the pipe as straight as possible, as bends or elbows increase the amount of power required to pull the air through them and still maintain the required suction and velocity. An elbow should have a center-line radius of 1½ to 2 times the diameter of the pipe. The resistance of this, however, is equal to a length of pipe ten times the diameter. Losses in pipes depend upon the size, length, velocity, and other factors. Most companies providing this type of equipment will supply tables for determining the requirements of a particular installation or will give advice and consultation on the problems involved.

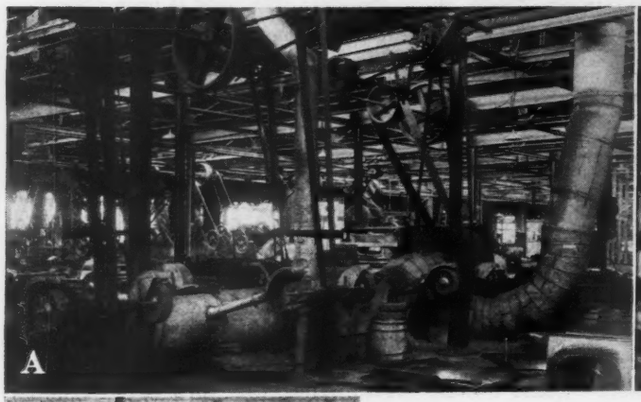
Another factor to be remembered is that the volume of air delivered by a fan varies directly as the speed, while the air pressure created changes in proportion to the square of the number of revolutions and the power required to drive the fan varies as the cube of the speed. In other words, doubling the speed of the fan doubles the volume delivered (which is the measure of the capacity), increases the air pressure created to four times (the square) that previously existing, and increases the power required to eight times (the cube) what it was at the original speed. These are factors which are often overlooked in an installation, particularly when the question arises of increasing its capacity or adding additional connections to machines. These points should be kept in mind when planning for an installation, because a unit to be operated at full-load capacity saves on the original cost but has a high cost of operation. On the other hand, an oversize fan costs more in the first place but has a

A dust collecting system with two fans each serving 14 machines.
The size of the fan depends upon the total area of the branch pipe served and is found by consulting data furnished by the manufacturer of the fan. The main varies in diameter from the dead ends towards the fan. This diameter at any point is 20 to 25 per cent greater than the sum of the areas of all pipes entering it up to that point.



How Dust Is Removed in Industrial Plants

Equipment and Methods That Have Wide Application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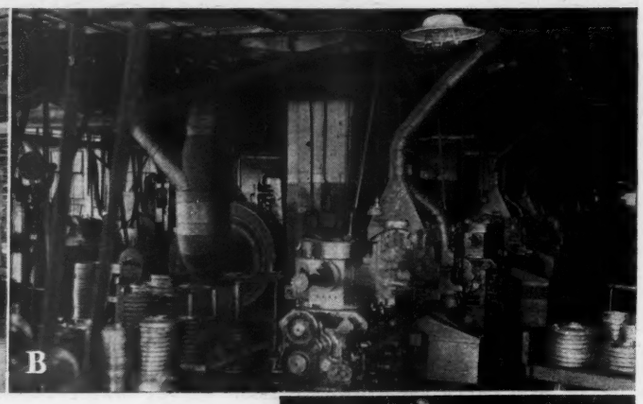
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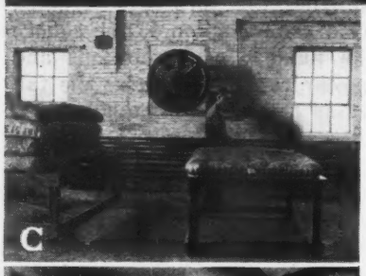
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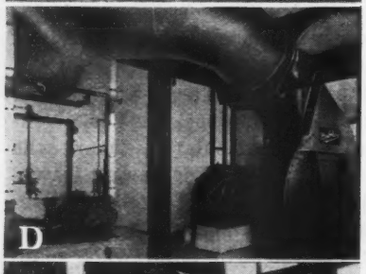
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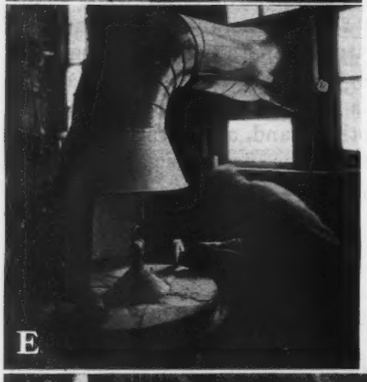

E

A—Here the exhaust main is placed between the rows of machines with small lead-off pipes from each machine. In some cases the exhaust main runs along on the ceiling of the floor below to save floor space.

B—Hoods, fitting closely around the machines, remove the cast-iron dust in the flywheel department of an automobile factory.

C—A propeller fan in the wall is used to remove the dust which arises when cleaning mattresses in a bedding factory.

D—All suction pipes, particularly connections from individual machines, should be provided with cut-off blast gates, similar to that shown in the outlet of a blower.

E—Here a propeller fan in a special hood is used to remove the fine dust caused when resurfacing paint grinding stones.

F and G—This portable electric tool for cleaning electrical and other machinery may be used as a blower F or as a vacuum cleaner G.

H—Another type of portable suction sweeping equipment used in cleaning telephone equipment. This is driven by a motor which gets its power from a lamp socket.

I—This vacuum sweeper is connected to heavy-duty equipment through pipes and hose. It is used here to gather up coal and dust from the floor in a power plant.

J—Propeller fans inserted in the windows are used here for general ventilation in a sandblasting room.

K—Hoods, such as one shown raised on the first machine, are placed over each machine to catch any lint which may be loosened. A blast gate in the pipe just above the hood enables each machine to be cut off when idle and so save on power used.

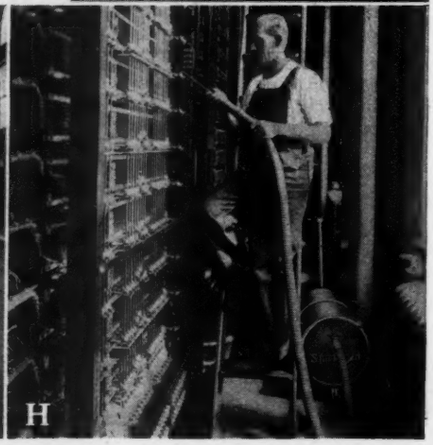
I

J

K

F

G

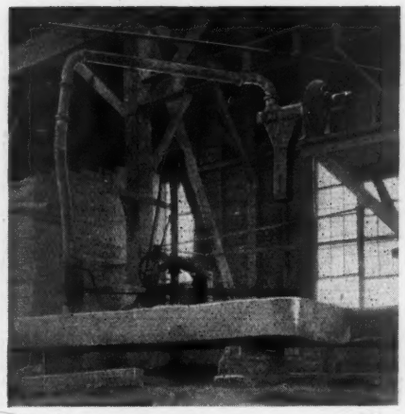

H

lower operating cost. Also, additional units may be added without causing a prohibitive overload.

Cutting off connections reduces the power required to operate, providing these unused inlets are tightly closed. For this reason it is well to provide cut-off slides in the connections between all machines and the main exhaust pipe so that any idle equipment may be cut out and the power required to operate the exhaust system reduced. Also, care should be taken to see that no small openings or leaky joints are permitted in the branch or main exhaust lines as each adds to the load on the system.

While it is always desirable to remove dust at its source, when possible, there are cases where it is not practicable to do this, as in certain kinds of sandblasting work. When this operation is performed on small articles, the sandblast is usually placed in a box where the operator holds the work in the desired position and watches it through a window. Air is exhausted from the top of the box and the fresh supply for replacement is drawn in through the hand holes.

In the case of larger work, where more space is needed, the whole apparatus is located in a small room, with the blast under a hood exposed to a strong exhaust. Generally the work is placed on a bench with a grating on top which is also connected to an exhaust. Fresh air is drawn in at the rear, as shown in the sketch on page 323, and tends to carry all dust away from the workman and into the hood or down through the bench. This same general scheme is often applied to other kinds of work where operating conditions are much the same.



Whenever possible, it is always best to remove dust at the source before it escapes into the room.

Here a special suction line is connected to the working hood of a stone cutting machine in a marble works. The flexible hose allows the machine to be moved about easily. As this dust is heavy and would have an abrasive action on the fan, it is removed through the special collector shown before it enters the fan.

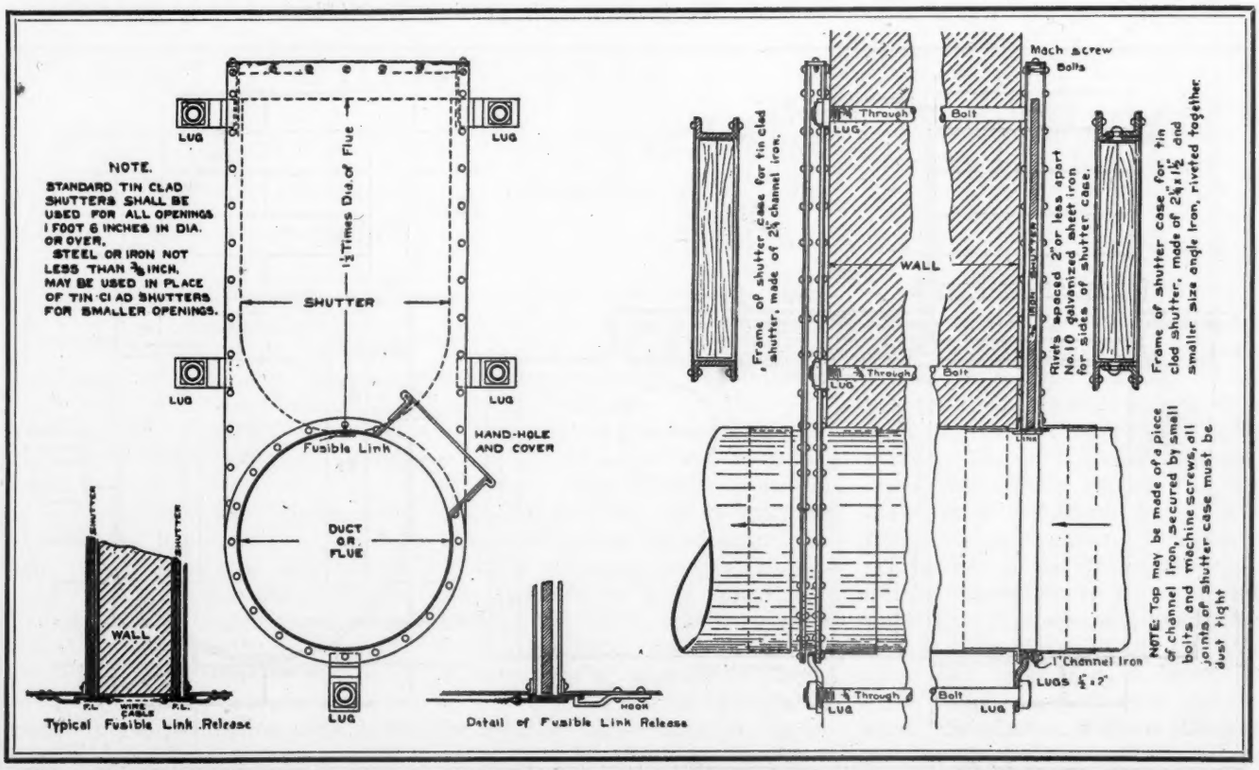
Several industrial plants build workbenches with gratings and a suction in the top. These are used particularly for working on brass and other castings. In this way the dust is drawn down and away from the worker, as produced. In other cases a suction hood is placed beside the work. One of the illustrations shows such a hood beside a bench used for cleaning furs. The furs are gone over by a small suction cleaner as shown and any dust or hair escaping is drawn away from the operator through the hood.

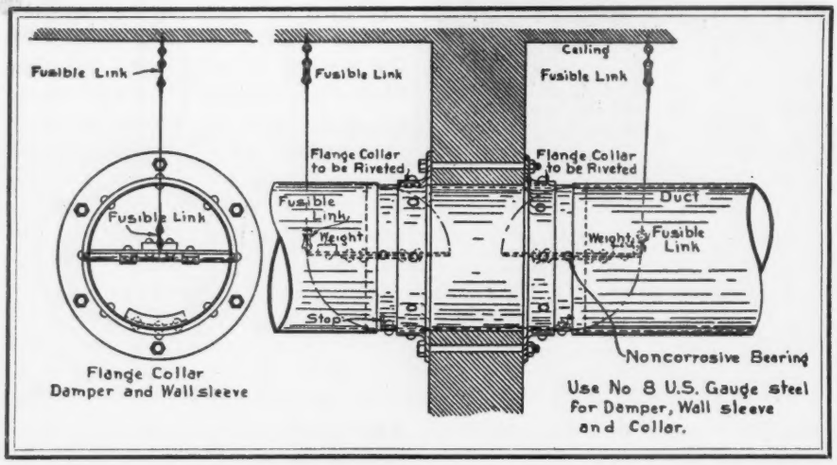
Where the dust particles are very fine, and not especially irritating, general room ventilating is usually sufficient, and this method is also used to a certain extent, even where suction hoods are applied at the source, to remove the dust which escapes these and passes into the air of the room.

While in most plants one or more central or departmental exhaust systems, each connected with a single fan, are employed, there are cases where individual units, or a number of small group systems are used economically and equally effectively. This generally occurs in establishments where there are compara-

A suggested type of vertical duct shutter for openings in fire walls.

Exhaust systems which gather lint or inflammable dusts may be provided with a vertical duct shutter where they pass through fire walls to prevent the passage of a fire from one part of the building to another. This shutter and the two devices on the following page are recommended by the National Fire Protection Association.


NOTE.
STANDARD TIN CLAD SHUTTERS SHALL BE USED FOR ALL OPENINGS 1 FOOT 6 INCHES IN DIA. OR OVER.
STEEL OR IRON NOT LESS THAN 3/16 INCH, MAY BE USED IN PLACE OF TIN CLAD SHUTTERS FOR SMALLER OPENINGS.
LUG
SHUTTER
1½ Times Dia of Flue
Fusible Link
HAND-HOLE AND COVER
DUCT OR FLUE
WALL
Typical Fusible Link Release
Detail of Fusible Link Release
Frame of shutter case for tin clad shutter, made of 2½ channel iron.
Through Bolt
Mach screw Bolts
Rivets spaced 2" or less apart No.10 galvanized sheet iron for sides of shutter case.
Frame of shutter case for tin clad shutter, made of 2½x1½ and smaller size angle iron, riveted together.
1" Channel Iron
Lugs ⅝x2"
NOTE: Top may be made of a piece of channel iron, secured by small bolts and machine screws, all joints of shutter case must be dust tight



Where the duct opening through fire walls is not over 12 in. in diameter automatic dampers such as these may be used.

Here dampers are placed in the pipe on each side of the fire wall and have fusable links both outside the duct and inside so as to drop the damper in case of a fire either within the room or within the duct.

tively few machines requiring dust removal and where these are located at wide intervals.

Pneumatic Sweeping and Cleaning of Plant and Machines

Removal, after the dust has settled upon the walls, floor, and on objects in the room, including the machinery, requires pneumatic sweeping equipment to secure the best results. This type of equipment is commonly termed a "vacuum cleaner" and consists of motor exhauster, and separator, arranged as shown in an accompanying sketch on page 321. The inlet to the separator is connected with a system of piping extending to all parts of the building, and provided with outlets for connecting a flexible hose and cleaning tool. The form and size of the tool depend upon the character of the work to be done and the nature of the surfaces to be reached, whether floors and walls or parts of machines and other irregular places difficult of access. When in operation, the exhaust maintains a partial vacuum in the separator, thus drawing in the dust-laden air from the cleaning tools through the system of connecting piping. Dust and air are separated in the tank, the air passing to the exhauster, from which it is discharged outside. A fairly strong suction is required for this work, depending upon the length of the pipe lines and other local conditions. Usually a suction of 6 in. of mercury column or about 80 in. of water is the maximum while 2 in. of mercury, or 27 in. of water is the minimum.

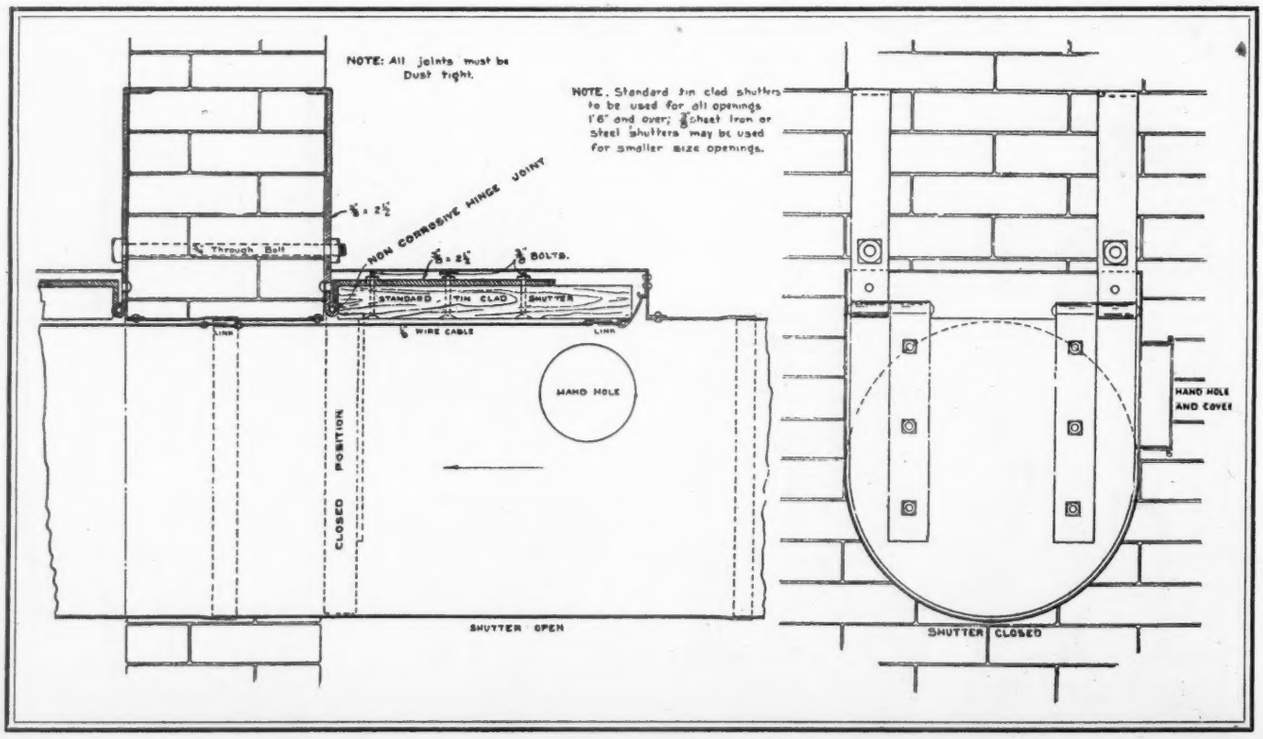
An installation based somewhat on this same general principle is used in the reconstructed Chicago and Northwestern grain elevator to keep down dust accumulation and so prevent another explosion. This system has 408 inlets all over the plant and a capacity whereby 24 men can sweep at a time. Two to three carloads of material are removed daily. This also gathers up any grain, which may drop from the conveyors or otherwise, along with the dust. Grain, however, is separated and saved. Rubber and other plants also employ pneumatic sweeping extensively to remove the dust which settles during the process.

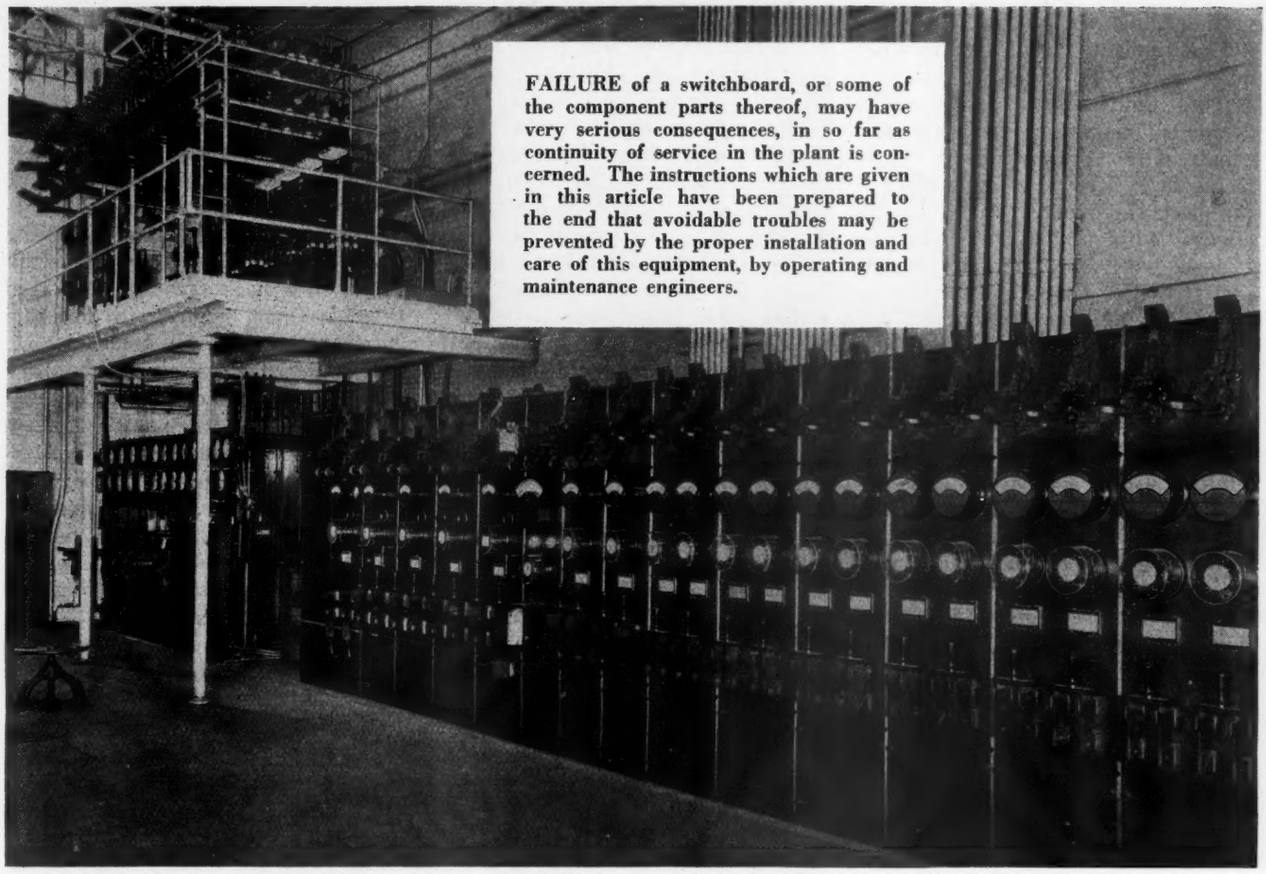
Recent practice makes use of lower pressures than were formerly

(*Please turn to page 355*)

Another type of automatic hinged duct shutter for openings in fire walls.

This shutter is also used to prevent the passage of fire, which may arise in a duct containing lint or other inflammable material, from one side of a fire wall to another. It is always advisable, if possible, not to extend ducts or other openings through fire walls. However, when such is necessary, devices such as this or the vertical shutter, shown on the preceding page, may be used.


NOTE: All joints must be Dust tight.
NOTE. Standard tin clad shutters to be used for all openings 1'6" and over; sheet iron or steel shutters may be used for smaller size openings.
NON CORROSIVE HINGE JOINT
Through Bolt
BOLTS.
STANDARD TIN CLAD SHUTTER
WIRE CABLE
LINK
HAND HOLE
HAND HOLE AND COVER
CLOSED POSITION
SHUTTER OPEN
SHUTTER CLOSED



FAILURE of a switchboard, or some of the component parts thereof, may have very serious consequences, in so far as continuity of service in the plant is concerned. The instructions which are given in this article have been prepared to the end that avoidable troubles may be prevented by the proper installation and care of this equipment, by operating and maintenance engineers.

This illustration shows part of the switchboard in a large steel mill. The feeders from the direct-current board, at the right, are carried up in conduit mounted on the wall behind the board. The oil switches mounted on the platform are controlled from the alternating-current board at the left. Note the method of supporting the buses on a pipe framework, on the platform. Courtesy of The Cutter Company, Philadelphia, Pa.

Recommendations of Electric Power Club on

Installation and Care of Power Switchboards

For the Guidance of Those Who Are Responsible for the Proper Operation and Maintenance of This Important Equipment

INSTRUCTIONS covering the installation, operation and care of power switchboards, oil circuit breakers and switching equipment have been issued under date of May, 1925, by The Electric Power Club, for the use of operating and maintenance engineers.

The Electric Power Club is an association of manufacturers of electric power apparatus and control equipment. The purpose of the organization is to devise standards of practice and construction in the design and application of electrical equipment, and to promote advancements in the production and use of such equipment.

In the introduction to the instructions for the installation, operation and care of power switchboards and switching equipment, the following comment is made:

"The successful operation of power switchboards and switching equipment depends upon proper installation and care, as well as upon proper design and manufacture.

"It is obviously impracticable to give instructions here applying to each of the many devices used to form a complete switchboard. The manufacturer's instructions given with each device should be consulted for detailed information on its installation, operation and care."

The instructions covering power switchboards are substantially as given below. Instructions for the operation and care of oil circuit breakers and switching equipment will be given in a succeeding issue.

Location of Switchboard

The switchboard in the modern power plant is seldom a self-contained device; many pieces of apparatus are necessarily located some distance away from the board proper. The switchboard manufacturer can usually render the customer great assistance in the selection of proper location, if drawings or sketches of the station are given to the manufacturer when placing the order. It is also safe to say that with full knowledge of the available space and conditions, a better or more suitable switchboard can be made. Details can, without affecting cost, be adapted to conditions.

In settling the location of switching equipment, first consideration must always be given to personal safety. Continuity of service often demands inspection, cleaning, and repair with a minimum of equipment out of service. Ample space is the best safeguard. Aisles should always be liberal, and particularly so if used when operating disconnecting switches, and when inspecting and adjusting other equipment.

Before attempting to install the switchboard the purchaser should make himself familiar with the regulations of the National Electrical Safety Code, The Electric Power Club's safety standards, and any local rules that may apply. Where local rules affect the design of the switchboard, the purchaser must bring such rules to the attention of the manufacturer before the switchboard is designed.

Mats of good quality rubber or other insulating material may be placed in front of the board and in the aisles, as a further protection to the operators.

Switchboard equipment designed for indoor installation must not be exposed to excessive moisture such as driving rain or condensation drop. It must be installed in a dry place, kept at a uniform temperature, and free from corroding fumes and abrasive dust. Any contemplated deviation from this rule should be referred to the manufacturer for advice. In locating the switchboard, precautions should also be taken to guard against strong drafts carrying the arc from air circuit breakers to ground.

Rheostats and resistances should be located so as to obtain sufficient ventilation, and so that one cannot transmit heat to another or to other apparatus.

Provision should be made for space for future growth, so that additional equipment can be installed with the minimum interference to service, and with the maximum factor of personal safety.

Erection of Panels

The switchboard is usually erected on a sill of 6-in. channel iron or 2-in. by 7-in. hard wood, carefully leveled and bolted to the floor after the panels, or at least the panel supports, have been erected on it. The channel sill should also be grouted to the floor by pouring thin concrete into it from the ends and through holes in the top, either before or after the erection of the panel frame. The panel frame is held by bolts tapped into the channel sill, or by lag screws if a wooden sill is used.

The method of anchoring panel braces is dependent on the construction of the wall. Heavy panel equipment requires solid fastenings. Expansion bolts, through bolts, or an angle iron bolted along the wall may be used.

The panel frame may consist of 1¼-in. upright pipe supports, angle irons, or channel irons for exceptionally heavy equipment.

Regardless of the frame construction and the method of shipping panels, whether assembled or dismantled, the middle panels should be erected first, and plumbed and braced securely. If the supports are shipped separately the framework should be set up and plumbed first, then the panels bolted to it, first loosely to avoid cracking, and then securely. Flexible washers must be placed between the frame and the panels. If shipped on its supports, each panel will be set up adjacent to the fixed panel and anchored in place. Shimming should be done between the sill and bottom edge of panels to plumb the free edge. Sometimes it may be necessary to file the edges of two adjacent panels by means of a hack saw blade inserted between them, in order to fit them closer together.

Benchboards are sometimes shipped assembled, but are more frequently knocked down. When erecting the board, the sills are leveled and bolted in place first; then the framework is set up and anchored to the sills; next the vertical sections below the bench sections are erected, always starting from the middle of the board; and last the instrument sections are set up. The grille or sheet-iron work should be fitted, but is sometimes not bolted into place until after wiring.

Frame Structure

Most of the frame structure other than that supporting the panels is

Fig. 1—This shows how the buses and feeders were mounted overhead in an installation in the Baltimore, Md., plant of the American Sugar Refining Co.

today made of 1¼-in. pipe with threadless fittings, because of its stiffness compared to its weight, its ease of assembling and adjustment, and its attractive appearance.

All such structures should be well braced together to avoid any flexibility that might tend to affect the operation of oil circuit breakers, or transmit jars from them to the panels. The threadless clamp fittings offer in this respect the best facilities for perfect adjustment.

In a heavy-capacity installation complete magnetic circuits should be avoided around a conductor carrying a great amount of current.

The frame must be effectively grounded and the paint removed from the pipes and fittings at the points of contact. There should never be more than three clamped or screwed joints in series for each ground connection.

Pipe caps should be slipped on the exposed ends of all pipes for improving the general appearance of the installation.

All metal work should be painted from time to time for protection and appearance.

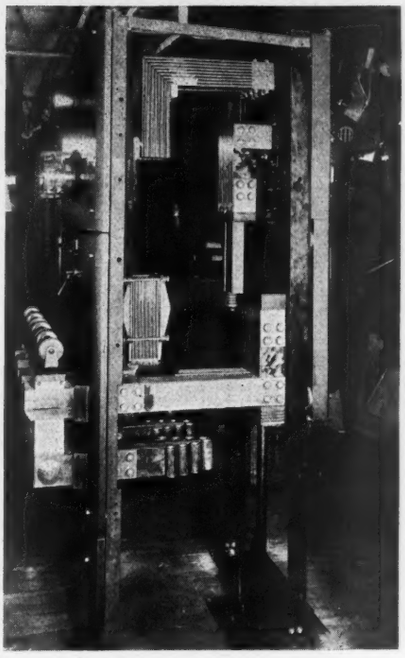


Fig. 2—Here is a neat way of arranging and supporting heavy buses at the back of the board.
Note the cable lugs and bus connections; also, that the angle-iron framework of the board is supported on a channel-iron sill. The circuit breaker which is mounted on a panel at the rear is controlled from the front of the board.

Main Connections

The main connections and the pipe framework may be fabricated, assembled and marked by the switchboard manufacturer. It is then a simple matter to install them by referring to the assembly drawings, which bear detail numbers corresponding to those stamped or stenciled on or tagged to the details. It is important to see that these drawings contain the latest revisions according to the shipping memorandum. When the apparatus is not assembled at the manufacturer's plant, the main connections, as well as the pipe framework, must be made at the point of installation.

Special attention should be given to all joints, whether clamped, bolted or soldered; all contact surfaces must be clean and smooth. Clamping and bolting must be such that the pressure is evenly distributed, and that there is no possibility of the opening of a joint due to vibration or to changes in temperature. This is particularly important where the connections and their joints are insulated after installation. Lock washers and locknuts are sometimes necessary.

It should be remembered that the conductivity of a bolted or clamped joint is proportional to the pressure applied at the joint. A poor joint may heat until the surface is annealed or oxidized, which in turn causes increased heating.

It should be remembered in making soldered connections that the solder has greater resistance than the copper, and therefore will heat if not sufficiently distributed over the entire joint. A heavy overload may cause heating sufficient to melt the solder, and care must be taken that there is no strain or tendency to separate such joints.

Iron clamps with steel bolts may be used in clamping connections for direct-current work, but for alternating-current connections and buses the clamps must be so constructed as to guard against magnetic circuits around individual conductors. This is especially important for heavy currents.

All contact surfaces of buses and copper conductors must be thoroughly cleaned with sand paper and oil immediately before they are clamped together. It is recommended that the purchaser extend this operation to the entire surface of the bars which are not to be insulated after installation, and then give them a coat of transparent lacquer to prevent tarnishing and to preserve a bright appearance. Every trace of oil must be removed before applying the lacquer. It is important that no lacquer should flow on the contact surfaces, and it is, therefore, best to do this work after the joints have been made. When changing buses that have been lacquered, the new contact surfaces should be washed clean with alcohol and then carefully scraped.

There should be uniformity and consistency in the order and arrangement of conductors for the sake of appearance as well as for convenience in caring for the equipment. This should be carried as far as practicable; for instance, on direct-current boards the positive bus and connections may be located nearest the board, nearest the top, and at the right-hand side facing the back of the switchboard. On alternating-current boards, phase 1 may occupy the same position as indicated above for the positive bus on direct-current switchboards.

Complications will naturally arise when the equipment is mounted away from the switchboard. It then becomes necessary to determine how far this uniformity should be carried through the station and to the lines. Local conditions and the size of the power system will be the governing factors in deciding this.

All buses and connections on the switchboard should be designed on the basis of a maximum temperature rise of 30 deg. C. above the room temperature. This limitation, and mechanical stability determine in general the size and shape of switchboard conductors. For the smaller current capacities, round conductors are frequently used as follows:

Conductors for Small Current Capacities

	Maximum Amperes
Bare Rod	
1/4 in. dia.	75
5/16 in. dia.	150
7/16 in. dia.	200
1/2 in. dia.	300
Insulated Wire	
No. 1/0 A.W.G.	175
No. 4/0 A.W.G.	300

Fig. 3 shows a method of approximating the amount of copper required for heavy buses and connections. Any special conditions should be referred to the manufacturer for advice, with full data on local conditions, because ventilation greatly affects the results.

Rigid supporting of all conductors is necessary, not only for appearance, but also to withstand any electromagnetic stresses which abnor-

mal conditions may produce. The short circuit force measured in pounds involves several factors, as for instance: the frequency and reactance of the circuit, the spacing and shape of the conductors, the construction of the supports, etc. Problems of this nature encountered in the installation of a switchboard should be referred to the manufacturer for advice.

In alternating-current installations, iron parts, such as supports, conduits, floor beams, etc., must not be placed between the different conductors of a circuit in such a manner as to form magnetic loops around a single conductor, and when dealing with capacities of about 2,000 amp. and above, care must be taken to avoid large masses of iron in close proximity to the circuit, as otherwise the iron will heat. This applies even to reinforcing material in concrete compartments.

Secondary and Small Wiring

All secondary connections from current and potential transformers to instruments should be metallic; the use of the earth as one of the conductors is in general not permissible.

Metallic conduit is recommended for all instrument and control leads between switchboards and other equipment, but care should be taken that all leads of one circuit are placed in one conduit. Control leads should not be placed in the same conduit with secondary leads; it is well to make provision so that any reasonable repairs or changes can be made without jeopardizing the continuity of service. If the secondary and control leads do not run beyond the switchboard room, they frequently enter the switchboard through conduits overhead; otherwise the best practice is to imbed the conduits in the switchboard floor, terminating about 2 or 3 in. above the finished floor, and as close to the terminal boards as possible. The top of the conduits must be provided with bell mouths or bushings to prevent injury to the insulation on the wires. The openings should be filled with wooden plugs or oakum after connections have been made.

The inside diameter of the conduit should be 30 to 35 per cent larger than the cable used in it. Uniformity of size, even if larger than necessary, is an advantage in appearance, as well as in purchasing the material. Sharp bends in the conduit must be avoided and the number of bends between outlets should be held down to not more than three or four. During construction work all conduit ends should be sealed by corks or wooden plugs until the cables are pulled in. Joints should be water tight, particularly if laid in concrete, and provision should be made for drainage to eliminate any water that may accumulate due to condensation or accidents. All conductors of a single-phase or polyphase circuit must be run in the same iron conduit; or fibre conduit may be used for individual conductors. A wire or steel tape should be used in pulling the cable through the conduit. This work is materially lessened if talc or soapstone powder is blown into the conduit or dusted on the cable. It is very important to clean the inside of the conduit before putting the cable through.

Recommended Thickness of V. C. Insulation on Conductors

Voltage Range	Number of Layers
0- 1,000	3
1,001- 2,000	4
2,001- 3,000	4
3,001- 4,000	5
4,001- 5,000	6
5,001- 6,200	7
6,201- 7,600	8
7,601- 8,800	9
8,801-10,000	10
10,001-11,600	11
11,601-13,400	12
13,401-15,400	13
15,401-17,400	14
17,401-19,400	15
19,401-21,200	16
21,201-23,200	17
23,201-25,000	18
25,001-26,800	19
26,801-28,000	20
28,001-30,400	22
30,401-32,800	24
32,801-35,200	26
35,201-37,600	28
37,601-40,000	30

NOTE: This table is based on the use of 0.010- or 0.012-in. varnished cambric.

Another method of entering the board from below is to let the conduits terminate in a trench just back of the switchboard sill. Insulating bushings, through which leads are brought up to the board, are set in a plate projecting slightly over the switchboard side of this trench. Removable plates cover the trench. This arrangement permits a certain amount of crossing of leads out of sight, so that they can be brought up to the board immediately below the terminal points. To make the connections easier, multi-conductor cable is usually furnished with different-colored braid on each conductor.

Solid wire may be used with flameproof covering for exposed wiring on the back of the switchboard, and on the framework. A fixed order of leads is followed as far as practicable in cleating wiring to the panels; for instance, for each panel or circuit the current leads may be brought up at the left side facing the rear of the switchboard, the potential to right, and the control leads in between.

No bare connections above 750 volts should be allowed in the switchboard room, or where connections are accessible from the aisles. Connections for about 11,000 volts and above are usually so far out of reach as to be harmless, and so well protected by space insulation as to preclude the necessity for wrapped insulation. The switchboard manufacturers cannot furnish these connections insulated because the taping should be continuous over the connections and the terminals or lugs. This is considered part of the installation material. It is also recommended that the purchaser insulate all connections and terminal lugs for circuits below 750 volts in which enclosed switches or oil circuit breakers are used. While a lever switch with bare live parts is in itself a caution notice, a device such as an oil circuit breaker, being enclosed, inspires confidence and invites dangerous contact with terminals and connections. It should, of course, be borne in mind that a carefully wrapped conductor may not be safe to handle alive.

In general, connections installed in compartments and those operating at 15,000 volts and above are not insulated. Since insulation has a tendency to increase the temperature rise of a conductor, the purchaser should not insulate connections designed to be left bare without first consulting the manufacturer.

The proper thickness of insulation for different voltages based on the use of 0.010-in. or 0.012-in. varnished cambric is suggested in the accompanying table. Over the outside layer of varnished cambric there should be applied cotton tape half-lapped and finally two coats of flame-resisting paint.

Ground Connections

A good and reliable ground connection is very important for every

switchboard installation. It should be of sufficient capacity to take care of any abnormal conditions that may occur on the system, and it should be independent of the grounds for lightning arresters and other power apparatus.

The secondary windings of all current and potential transformers should be connected to ground at the transformers and without fuses. If for any reason this cannot be done, as for instance with instruments and meters having secondary current and primary potential coils, the secondary wiring must be insulated and installed to withstand primary potential with safety.

All metal conduits should be grounded.

The switchboard frame should be grounded at every upright support, and care should be taken to remove the paint on fittings and pipe to permit a good connection. The channel sill should be grounded in this manner by a perfect contact with the supports.

Exceptions—An insulated frame should be used for single-polarity, direct-current switchboards of 700 volts or less with grounded negative.

Switchboard devices for operation at 150 volts or more above ground potential should have their exposed metal frame parts permanently grounded when these are insulated from the current-carrying parts and not isolated by elevation or otherwise permanently protected. This rule covers, for example, transformers and alternating-current instrument casings, operating mechanisms for switches and oil circuit breakers, oil circuit breaker frames, rheostats, compensators, etc. This is usually accomplished by connection to ground buses, of a cross-section not less than No. 2 A.W.G., which should run the entire length of the switchboard, and the oil breaker structure, if the two are separate.

Steel work and frames for high-voltage switching equipment should be grounded at several points to guard against insulation at the joints. There should never be more than three clamped or screwed joints in series for each ground connection, and for high-voltage apparatus there should be less.

There are various methods used to secure a ground connection. One plan is to drive galvanized iron pipes of about ¼ in. diameter into permanently moist earth, spacing them about 8 ft. apart along the side of the station, and joining them together by a copper strip about 1 in. by ⅛ in. The pipes should be kept filled with rock salt. The ground connection should be made to this system of pipes at two or three points, and all joints riveted and soldered, or brazed.

Another method in many cases preferable is to bury a copper plate, about 3 ft. square, in permanently moist earth with a layer of crushed coke or charcoal about 2 ft. deep, both below and above it. The ground cable, which should be riveted and soldered across this plate, should be brought into the station and securely connected to the different ground buses.

Work on current-carrying parts should not be undertaken until these parts have been disconnected from the system and connected to the ground bus. Provision should be made, therefore, by the purchaser for connecting flexible ground leads so as to reach every part of the switching equipment.

Illumination of Switchboard

The switchboard should be amply illuminated both front and back by the station lighting system, and it is well to provide some emergency system so that the switchboard room cannot be put in darkness under any abnormal condition. In stations with storage batteries, this can be accomplished most easily by means

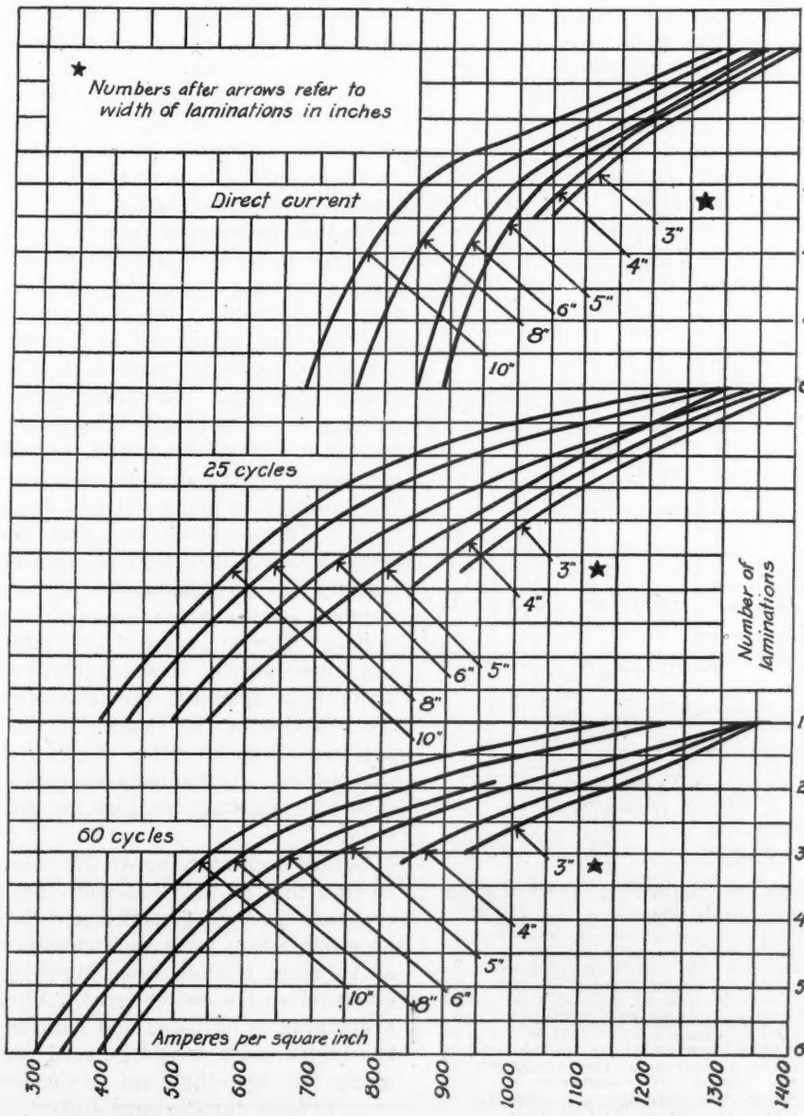


Fig. 3—Current-carrying capacity of usual sizes of copper buses.

These curves refer to buses composed of laminations ¼ in. thick with ¼-in. spacing between laminations, and an allowance of 8 in. between phases. The values given may be used for currents not exceeding 3,000 amp., and are based on a 30-deg. C. rise at an ambient temperature of 40 deg. C. The use of two ⅛-in. thick laminations in place of one ¼ in. thick strap gives increased capacity due to increased radiating surface. However, this advantage is gradually offset by inductance as the number of laminations per phase increases and as the spacing decreases.

of automatic throw-over switches, which, on failure of the normal lighting circuit, throw a number of lights on to the battery.

Phase Rotation

A method which is often most convenient for testing out the connections for phase rotation is to use a small induction motor connected to the line or to the machine direct, or through potential transformers. Another simple method is that shown in Fig. 4. One of the lamps will glow more brightly than the other. If lamp *B* is brighter, phase rotation is clockwise, or 1, 2, 3. If, on the contrary, lamp *A* is the brighter, phase rotation is 3, 2, 1, or counter-clockwise. It is always a wise plan to study carefully the instructions sent with the machine before connecting it up for operation.

Synchronizing

The following instructions serve for testing the connections of the synchronism indicator or synchroscope, and for emergency conditions. Unless the two polyphase circuits have already been running in parallel, so that there is no question about the sameness in phase rotation, two phases should be checked. Connections may be made as in Fig. 5 with the circuit breaker open. When the electromotive forces of the two sources are exactly equal and in phase the current through the lamps is zero. As the phase difference increases, the lamps light up, and at 180 deg. out of phase they will all burn with full voltage. The rate of pulsation of the lamps depends upon the difference in frequency of the two polyphase circuits. So far it has been assumed that the phase rotations of the circuits to be synchronized are the same. However, should the two sets of lamps, the lamps in the two phases, not pulsate in unison, it is safe to say that the phase rotation of the two sources is not the same, and changes should be made in the order of the main connections until the desired indication is obtained.

Only one set of lamps is necessary for single-phase circuits, as there is no question of phase rotation. The method just described here is termed synchronizing with dark lamps. To determine whether the lamps will be dark or bright for a given synchronizing connection when the machines are in phase, the main leads should be disconnected

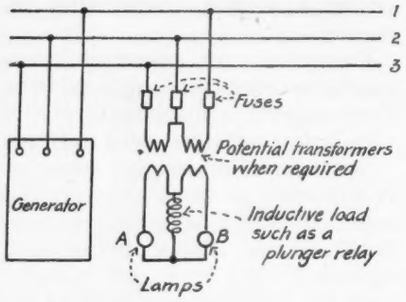


Fig. 4—Here is a simple method of determining phase rotation.
With the connections shown one of the lamps will be brighter than the other. If lamp *B* is brighter than lamp *A*, phase rotation is 1, 2, 3, or clockwise. If lamp *A* is brighter, phase rotation is 3, 2, 1, or counter-clockwise.

at the generator and the circuit breaker closed. Since both circuits are then connected to one source of power, the lamp indication will be the same as if the circuit breaker were open and the separate sources of power were in synchronism.

It is extremely important in all such synchronizing connections that the indication represent the condition of the circuits at the circuit breaker, which is to parallel the circuits. In other words, if there are transformers in one of the circuits to be synchronized, they must be outside the synchronizing connections, as in Fig. 5, otherwise there is a danger of there being a synchronous indication while the circuits are in direct opposition.

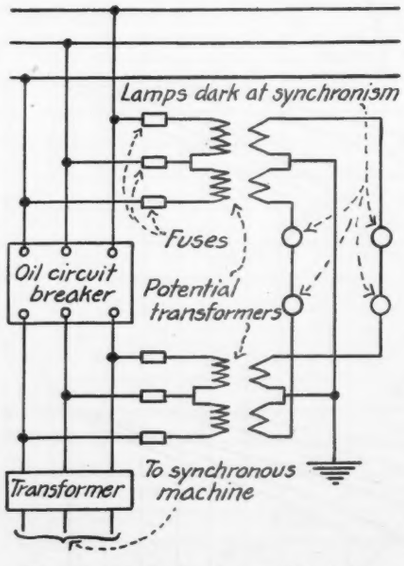


Fig. 5—Method of synchronizing with dark lamps.
The connections of the synchronizing device should be made as indicated, with the circuit breaker open. When the two circuits are 180 deg. out of phase, the lamps will glow with full brilliancy. Assuming that the voltages of the circuits are equal, as the phase difference decreases the brilliancy of the lamps will decrease so that when the circuits are exactly in phase the lamps will be dark.

Ground Detectors

It is frequently necessary on ungrounded systems, alternating current as well as direct current, to install some kind of equipment for detecting or reading leakage to ground. The simplest method for low voltage, two-wire systems is to connect two lamps of the system voltage in series across the two wires, with the connection between the two lamps grounded. A ground on one side will obviously short-circuit and darken the lamp on that side. A static or glower type of ground detector instrument is generally used for voltages above 300.

Operation

Inasmuch as the switchboard controls all of the machinery and other apparatus in the station, it is most essential to its proper operation that the operator become familiar with all general and special instructions referring to the apparatus.

Before putting the switchboard into service, all connections to instruments, meters, relays, etc., should be carefully checked with the drawings and care should be taken to see that resistances are connected in all the meter and instrument circuits requiring them. A preliminary trial should then be made to see that the instrument and meter equipment reads or records in the proper direction. In fact, before putting a switchboard into actual service, it is advisable to put current through all parts at reduced potential in order to bring out any weak spots. The potential and load can then be slowly increased to normal.

Every detail should be closely watched, and anything out of the ordinary should be carefully noted and investigated. The switchboard manufacturer invites information on the behavior of the equipment, and welcomes opportunities to assist with advice. Any defects discovered should be reported to him immediately.

Before each starting of the plant, be sure that all switches and circuit breakers involved are open and that no other device is in such condition as to cause trouble when throwing potential on the switchboard. After everything is adjusted and running, the instruments should be read regularly to see that no device or

(*Please turn to page 350*)

Methods of

Taking and Recording Rewinding Data

On D. C. Armatures so That All of the Details of the Winding Will Be Noted in Such a Manner That Any Winder Can Use the Data

By A. C. ROE

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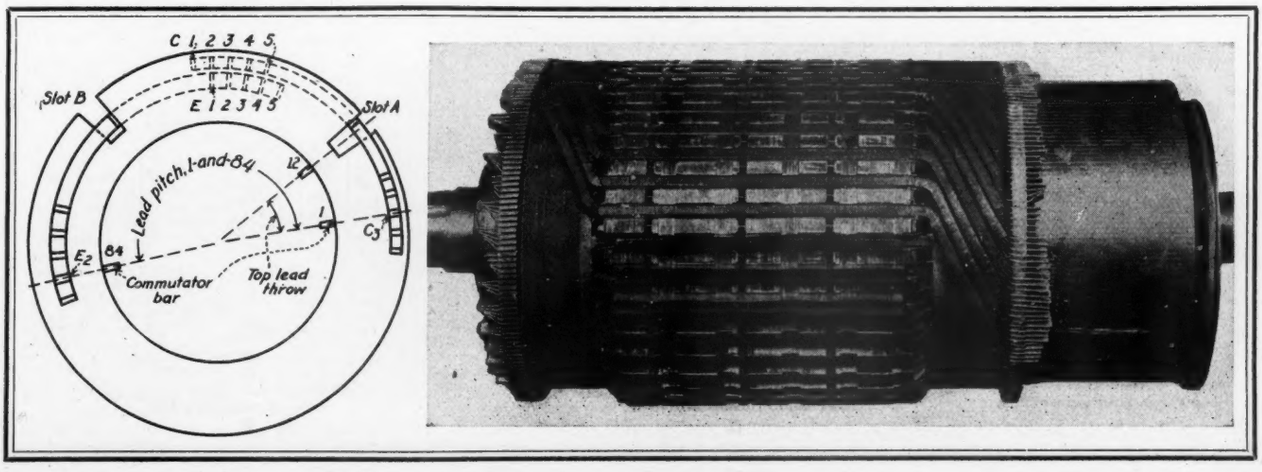
IT IS VERY easy to leave out some important detail when taking the data on an armature that is to be rewound. This is particularly true in the case of direct-current armatures, for in addition to the data concerning the coils, data must be taken in connection with the commutator. This is the second of a series of articles on this subject by Mr. Roe. The first article was published in the June issue and gave some of the more simple methods that he has found to be of value. This article describes some rather elaborate forms which may be useful in your repair shop.

TAKING the rewinding data on the armatures of direct-current motors is a very important part of the motor repair job if the repaired armature is expected to duplicate the performance of a new one. If an important detail is incorrectly recorded or omitted, costly mistakes may be made in rewinding the armature. To insure that the data are completely and correctly recorded, a systematic method of taking and recording them should be followed. In the June issue of INDUSTRIAL ENGINEER, details of three methods of taking these data were given. The first of these methods is very simple and will undoubtedly fill the needs of a small repair shop handling a limited variety of motors. The second method is more comprehensive in scope and will meet the needs of many larger shops. The third method is very complete and covers practically all of the more usual types of direct-current armatures.

There is no one best method that can be used for all kinds of windings. One method is sometimes more suited to one type of winding than to another. However, another method may be more easily understood by the men who have to use it. It is for this reason that in what follows several other methods are given, which many winders will undoubtedly desire to use.

In the forms that were described in the preceding article the lead throw was counted from, or based on, the center line of the slot that holds the bottom coil side. In other words when taking the data on a winding, the slots containing the top and bottom coil sides of a selected coil were first located. The slot holding the bottom coil side was called slot *1* and this slot was used as a base in determining the number of the slot holding the top side of the coil. Next was found the commutator bar to which the lead from the bottom coil in slot *1* was connected. This bar was called bar *1* and, counting from this bar as a base, the bars connecting to the top coil side and also the bar or mica between two bars which were in line with slot *1*, were located. From this the coil throw, lead throw, and the lead pitch were found.

In Fig. 3 are shown forms for recording rewinding data, which use the center line of the coil as a base in determining the lead throw, instead of the center line of the slot containing the bottom coil side, as was the case in the preceding article. Diagram *A* shows a winding unit having five coils per cell. The center of this winding unit or bunch of coils falls on slot *4* and also on commutator bar *32*. In determining the lead throw, the center coil of the winding unit is used as a base, as is



Figs. 1 and 2—Method of taking data on strap-wound armature. Inspection of the diagram and the illustration of the armature that it represents will show that each slot contains two half-coils or winding units, each of which consists of five straps. *C1*, *C2*, *C3*, *C4*, and *C5* are the top straps, and *E1*, *E2*, *E3*, *E4* and *E5* are the bottom straps. The inner circle represents the commutator. The important thing to know is which top strap connects at the rear to a given bottom strap. In the winding shown the strap *C3* from slot *A* is connected at the rear to strap *E2* from slot *B*. The front end of strap *C3* is connected to commutator bar *1* while the front end of strap *E2* is connected to bar *84*. Consequently, the lead pitch is said to be 1-and-84, C3-E2. Commutator bar *12* is directly under the center of slot *A*; hence the top lead throw is said to be 1-and-12.

shown in the diagram. Counting from the adjacent bar to the one on which the center line of the coil falls, we find that the center lead from the bottom coil side falls on a bar which is 31 bars away from the reference bar in line with the center of the coil. The same is true for the center lead of the top coil side. The bars may be numbered as given, or better, the bar connecting to the center bottom lead may be called bar *1*, the bar on the center line of the coil may be called bar *32*, and the bar connected to the center top lead may be called bar *63*. This is indicated in the diagram.

In *B* of Fig. 3 is shown a similar diagram for a coil, the center line of which falls on a tooth and upon the mica between two bars. It also shows the manner of indicating a dead coil.

In *C*, *D* and *E* of Fig. 3 are incorporated all the good points of the preceding data forms. Diagram *C* is for lap windings while *D* and *E* are for wave windings. In each of these three diagrams it will be noticed that two arrangements of slots are shown. The top arrangement is for use when the center line of the coil falls on the center of a slot, while the lower arrangement is used when the center line of the coil falls on the center of a tooth. In each case the slot marked *A* is taken as the slot holding the bottom coil side and is called slot *1*. Slot *F* locates the center of the coil if the coil center falls on a slot; if it falls on a tooth, slots *E* and *D* locate the coil center. Slot *B* holds the top coil side.

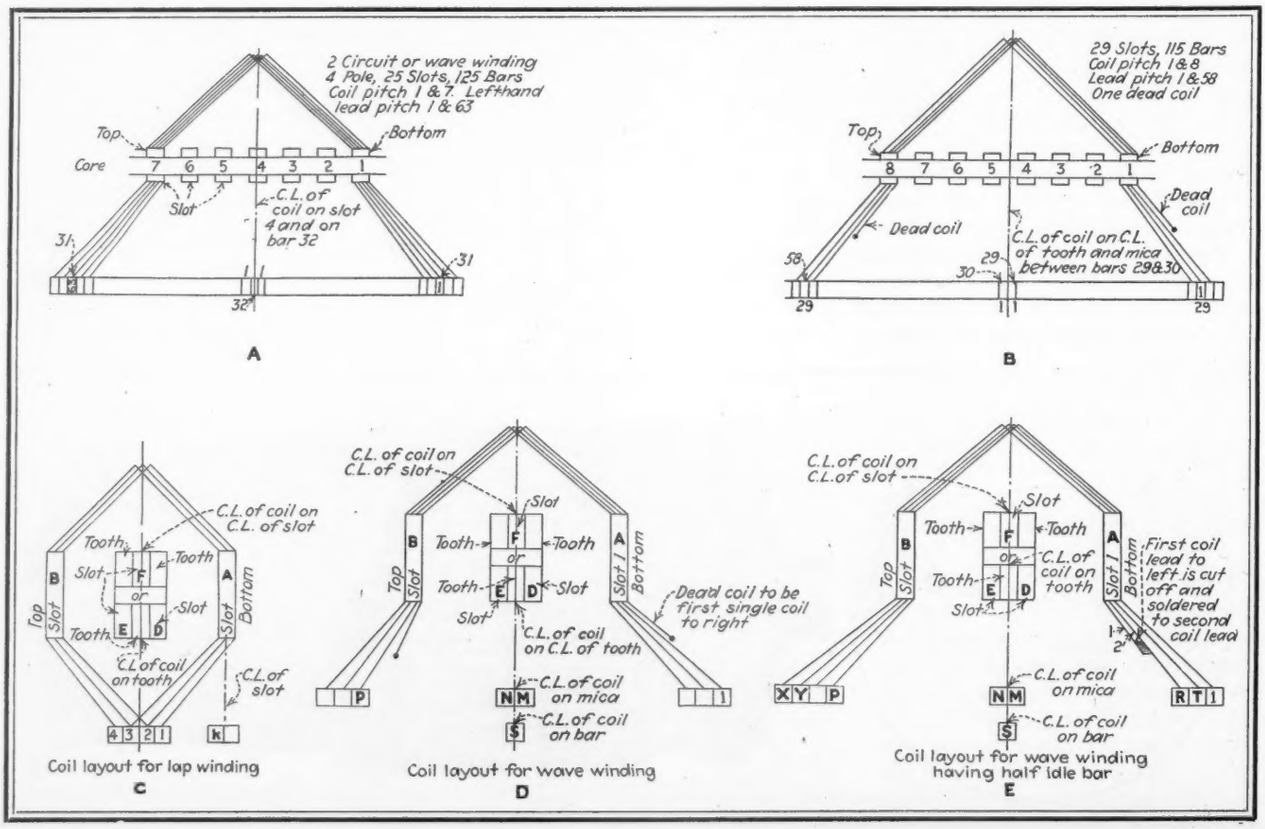
In diagrams *D* and *E* provision is made for when the center line of the coil falls on the bar, as well as when it falls upon the mica between two bars. Bar *S* is located in the former case and bars *M* and *N* in the latter.

Diagram *D* also shows the method of indicating a dead coil while diagram *E* gives the method of showing a long-jumper connection, which was described in the preceding article on page 284 in the June issue.

Fig. 3—Data forms that will give the winder exact information for locating the commutator, core, and coils with respect to each other.

In diagrams *A* and *B* is shown a method of taking rewinding data using the center of the coil as a reference point in locating the slots holding the coil as well as the bars to which the leads of that coil are connected. In *C*, *D* and *E*, this idea has been followed out more elaborately. These diagrams will take care of cases in which the center line of the coil falls upon the center of a tooth or upon the center of a slot, as well as when the center of the coil falls on a bar or on the mica between two bars. *C* is for use with lap windings, while *D* and *E* are for use with wave windings.

Figs. 4 and 5 show another method of taking the rewinding data. The form used is quite elaborate. Diagram *A* of Fig. 4 shows the data as taken for an armature having 39 slots and 195 commutator bars. In taking these data, a coil was selected and the bottom and top coil sides were located. The slot holding the bottom coil side was called slot *1* as shown in the diagram and counting from this coil side to the slot holding the top coil side, the latter slot was found to be slot *11*. The slot in line with the center of the coil was found to be slot *6*. The center line of slot *6* was found to line up with the mica between commutator bars *48* and *49* as shown in diagram *A*. The numbers of these commutator bars were found by taking as bar *1* the bar to which the first lead of the bottom coil side in slot *1* was connected. Likewise the bar to which the corresponding lead of the top coil side was connected, was found to be bar *98*. The commutator bars to which the leads of this winding unit are connected, are punch marked as shown in the diagram. To distinguish the bars to which the leads of the top coil side are connected, the group of bars to which these leads are connected are marked with an extra punch mark, as shown. Also the bars that are in



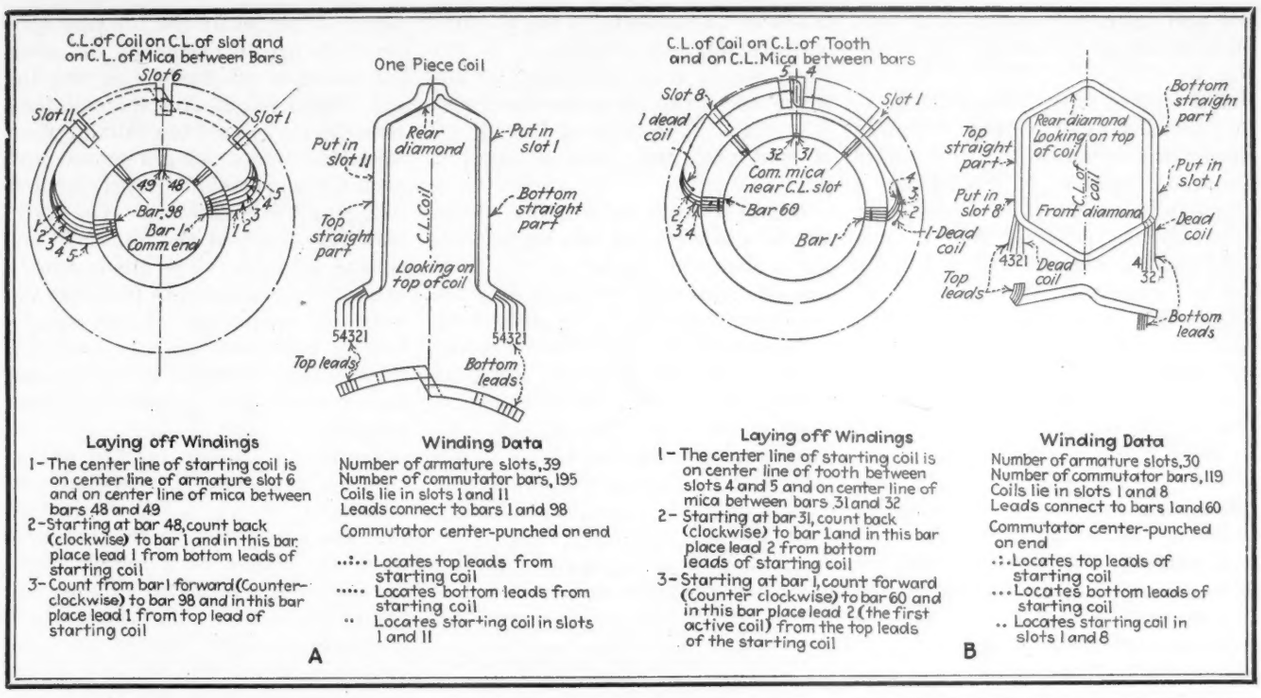

C.L. of Coil on C.L. of slot and on C.L. of Mica between Bars
Slot 6
Slot 11
Slot 1
Bar 98
Bar 1
Comm end
One Piece Coil
Put in slot 11
Rear diamond
Put in slot 1
Top straight part
C.L. Coil
Bottom straight part
Looking on top of coil
54321
Top leads
Bottom leads
Laying off Windings
1 - The center line of starting coil is on center line of armature slot 6 and on center line of mica between bars 48 and 49
2 - Starting at bar 48, count back (clockwise) to bar 1 and in this bar place lead 1 from bottom leads of starting coil
3 - Count from bar 1 forward (Counter-clockwise) to bar 98 and in this bar place lead 1 from top lead of starting coil
Winding Data
Number of armature slots, 39
Number of commutator bars, 195
Coils lie in slots 1 and 11
Leads connect to bars 1 and 98
Commutator center-punched on end
Locates top leads from starting coil
Locates bottom leads from starting coil
Locates starting coil in slots 1 and 11
A
C.L. of Coil on C.L. of Tooth and on C.L. Mica between bars
Slot 8
Slot 1
1 dead coil
Com. mica near C.L. slot
Bar 60
Bar 1
1-Dead coil
Bottom straight part
Top straight part
Rear diamond Looking on top of coil
C.L. of coil
Put in slot 1
Put in slot 8
Front diamond
Dead coil
4321
Dead coil
Top leads
Bottom leads
Laying off Windings
1 - The center line of starting coil is on center line of tooth between slots 4 and 5 and on center line of mica between bars 31 and 32
2 - Starting at bar 31, count back (clockwise) to bar 1 and in this bar place lead 2 from bottom leads of starting coil
3 - Starting at bar 1, count forward (Counter clockwise) to bar 60 and in this bar place lead 2 (the first active coil) from the top leads of the starting coil
Winding Data
Number of armature slots, 30
Number of commutator bars, 119
Coils lie in slots 1 and 8
Leads connect to bars 1 and 60
Commutator center-punched on end
Locates top leads of starting coil
Locates bottom leads of starting coil
Locates starting coil in slots 1 and 8
B

Fig. 4—This method of taking data gives the winder a true picture of the coil in the slots, showing the relationship existing between core, coil and commutator.

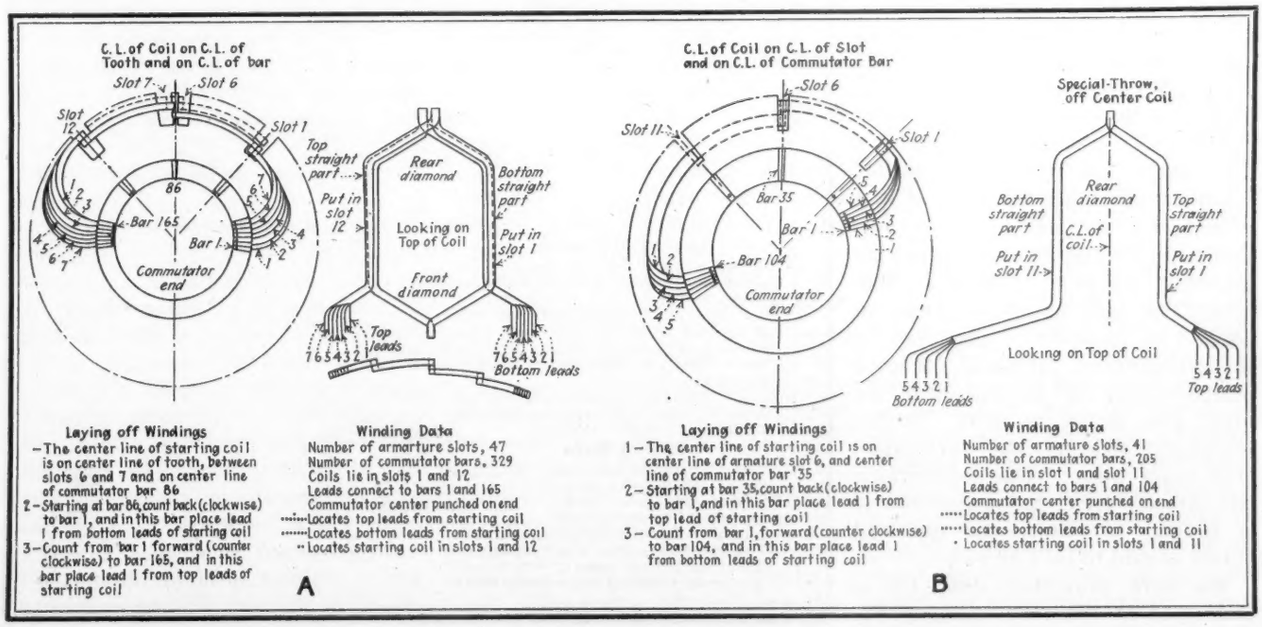
With this method of recording the data four cases arise. One is where the center line of the coil falls on the center of a slot and also on the mica between two commutator bars, as shown in diagram *A*. Another is when the center line of the coil falls on the center of a tooth and on the mica between two bars, as shown in diagram *B*. The other two cases are illustrated in *A* and *B* of Fig. 5. In diagram *A* is shown a winding unit having five coils. The one shown at *B* has four coils, one of which is a dead coil.

line with slots *1* and *11* are punch marked so that the starting coil slots will be located with reference to the commutator. These punch marks eliminate the chance of getting a retrogressive winding in place of a progressive winding or vice versa. The procedure in laying off the winding from the data is given in the notes under the diagram.

Four different types of blank forms are required if this method is used. One should be made up similar to *A* of Fig. 4, in which the center line of the coil falls upon the center line of a slot and also upon the mica between two bars. Another form would be required where the center line of the coil falls on a tooth and on the mica between two commutator bars. Such a form is shown in *B* of Fig. 4. A third form is required where the center line of the coil falls on the center line of a tooth and on the center of a commutator bar. This form is illustrated in *A* of Fig. 5. A fourth form is required for the case in which the center line of the coil falls on the center of a

Fig. 5—These two forms are used in connection with those shown in Fig. 4.

When the center line of the coil falls on the center of a tooth and on a bar, the diagram shown at *A* is used. This diagram also shows the method of indicating a winding unit having seven, two-turn coils. If the center line of the coil falls on the center of a slot and a bar, the diagram shown at *B* is used. This diagram also illustrates the method of showing a special-throw, off-center coil.


C.L. of Coil on C.L. of Tooth and on C.L. of bar
Slot 7
Slot 6
Slot 12
Slot 1
86
Bar 165
Bar 1
Commutator end
Top straight part
Rear diamond
Bottom straight part
Put in slot 12
Looking on Top of Coil
Put in slot 1
Front diamond
Top leads
765432
7654321
Bottom leads
Laying off Windings
1 - The center line of starting coil is on center line of tooth, between slots 6 and 7 and on center line of commutator bar 86
2 - Starting at bar 86, count back (clockwise) to bar 1, and in this bar place lead 1 from bottom leads of starting coil
3 - Count from bar 1 forward (counter clockwise) to bar 165, and in this bar place lead 1 from top leads of starting coil
Winding Data
Number of armature slots, 47
Number of commutator bars, 329
Coils lie in slots 1 and 12
Leads connect to bars 1 and 165
Commutator center punched on end
Locates top leads from starting coil
Locates bottom leads from starting coil
Locates starting coil in slots 1 and 12
A
C.L. of Coil on C.L. of Slot and on C.L. of Commutator Bar
Slot 6
Slot 11
Slot 1
Bar 35
Bar 1
Bar 104
Commutator end
Special-Throw, off Center Coil
Bottom straight part
Rear diamond
Top straight part
C.L. of coil
Put in slot 11
Put in slot 1
Looking on Top of Coil
54321
Bottom leads
54321
Top leads
Laying off Windings
1 - The center line of starting coil is on center line of armature slot 6, and center line of commutator bar 35
2 - Starting at bar 35, count back (clockwise) to bar 1, and in this bar place lead 1 from top lead of starting coil
3 - Count from bar 1, forward (counter clockwise) to bar 104, and in this bar place lead 1 from bottom leads of starting coil
Winding Data
Number of armature slots, 41
Number of commutator bars, 205
Coils lie in slot 1 and slot 11
Leads connect to bars 1 and 104
Commutator center punched on end
Locates top leads from starting coil
Locates bottom leads from starting coil
Locates starting coil in slots 1 and 11
B

slot and upon the center of a bar. Such a form is shown in *B* of Fig. 5.

The method of indicating the location of a dead coil on these forms is shown in diagram *B* of Fig. 4. Likewise the manner of indicating a half-idle bar is shown in *A* of Fig. 5. Diagrams *A* and *B* of Fig. 4 show windings having five and four coils per cell, respectively. Diagram *A* of Fig. 5 shows a winding having seven coils per cell. This winding uses a coil that has two turns and is of the type known as double loop roll; that is, the coil has one loop or roll in front and a double loop or crossover at the rear diamond point. The double loop at the rear eliminates crossing the bottom leads over the coil side as the bottom leads are brought out on the bottom of the bottom half of the coil and the top leads are brought out at the top of the top half of the coil.

Many of the larger, heavy-duty motors, particularly railway-type motors, use half coils. In Fig. 1 is shown a diagram for recording the data on windings using half-coils. Such a winding is shown in Fig. 2. In this particular winding it can be seen that each half-coil is made up of five straps that are insulated from each other and assembled as one winding unit.

As can be seen from Figs. 1 and 2, there are two half-coils per slot, one in the bottom and one at the top. In Fig. 1, the top straps in a slot are designated by the letter *C* and the bottom straps in a slot by the letter *E*. Each strap is numbered from *1* to *5*. The inner circle in the diagram represents the commutator. The front end of the second strap in the bottom of slot *B*, that is, the *E2* strap, connects to commutator bar *84*, while the third strap at the top of slot *A*, that is, strap *C3*, connects to commutator bar *1*. The rear end of strap *C3* is clipped to the rear end of strap *E2*. In other words, the two half-coils, *C3* and *E2*, are clipped together at the rear to make a whole coil. The lead pitch will then be seen to be 1-and-84 as measured on the commutator. However, to give complete data on the lead pitch, we must give it as 1-and-84, C3-E2, thereby indicating the "creeping" that takes place. The commutator bar directly under the center of slot *A* is bar *12*; hence the top lead throw is said to be 1-and-12.

We have said that strap *C3* is connected at the rear to strap *E2*. Likewise *C4* connects to *E3*, *C5* connects to *E4*, and *C2* connects to *E1*. Thus we see that we "creep" or advance one strap in going from slot *B* to slot *A*. The effect of "creeping" is somewhat the same as a split pitch.

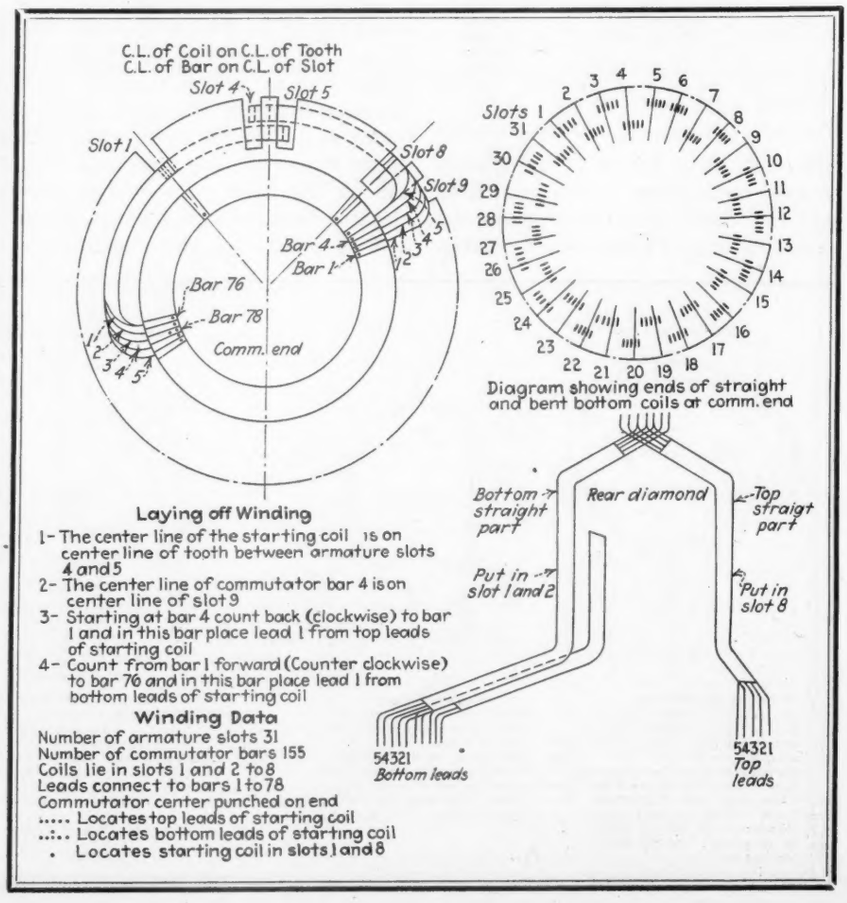
A jig is used in winding strap-wound armatures of this type. This jig is shown at the left of Fig. 2. It has as many slots cut in it as there are commutator bars, the slots being deep enough for two straps plus any fillers or spacers required, including a snug fit for the copper thickness used in the coil. The jig acts as a dummy commutator and lines up the rear end to receive the connecting clips. After all of the top and bottom coils are in place, the coil ends are trimmed off flush with the jig and a band is put over the coil ends near the jig to hold the coils in place while the jig is being removed and during the operation of applying and soldering the connectors. The jig is then removed and the clips are put on and soldered. The advantage in using the jig lies in the fact that the coils are evenly cut off and can be readily connected up. In addition, the armature is easier to balance and has a true line appearance when running.

A more elaborate method of recording the data for a half-coil winding is shown in Fig. 6. In this case the center line of the coil falls upon the center of a tooth. Also, the center line of bar *4* falls on the center of slot *8*. This locates the commutator with respect to the armature slots. The top lead throw, as can be seen from the diagram at the left and from the lower right-hand diagram, is very small—about one slot. Most of the lead throw is in the bottom leads.

This armature has three different shapes of half-coils. There are 31 top half-coils that are all alike. There are also 31 bottom coils, 16 of

Fig. 6—Here is a very elaborate method of recording the data for a winding using half-coils.

The diagram at the left gives the coil pitch, lead pitch and lead throw as well as the relation existing between the core, coil and commutator. The lower right-hand diagram shows the three shapes of half-coils that are used. All of the 31 top half-coils are the same. Sixteen of the bottom half-coils are straight as shown in the diagram while 15 of them have a U-shaped bend at the commutator lead end so as to fit into the winding space available. The upper right-hand diagram gives the location of the straight and bent bottom coils at the commutator end. The inner circle of lines represents the bent coils, while the outer circle of lines represents the straight coils.


C.L. of Coil on C.L. of Tooth
C.L. of Bar on C.L. of Slot
Slot 4
Slot 5
Slot 1
Slot 8
Slot 9
Bar 4
Bar 1
Bar 76
Bar 78
Comm. end
1 2 3 4 5
Slots 1 31
Diagram showing ends of straight and bent bottom coils at comm. end
Bottom straight part
Rear diamond
Top straigt part
Put in slot 1 and 2
Put in slot 8
54321 Bottom leads
54321 Top leads
Laying off Winding
1- The center line of the starting coil is on center line of tooth between armature slots 4 and 5
2- The center line of commutator bar 4 is on center line of slot 9
3- Starting at bar 4 count back (clockwise) to bar 1 and in this bar place lead 1 from top leads of starting coil
4- Count from bar 1 forward (Counter clockwise) to bar 76 and in this bar place lead 1 from bottom leads of starting coil
Winding Data
Number of armature slots 31
Number of commutator bars 155
Coils lie in slots 1 and 2 to 8
Leads connect to bars 1 to 78
Commutator center punched on end
..... Locates top leads of starting coil
..:.. Locates bottom leads of starting coil
. Locates starting coil in slots 1 and 8

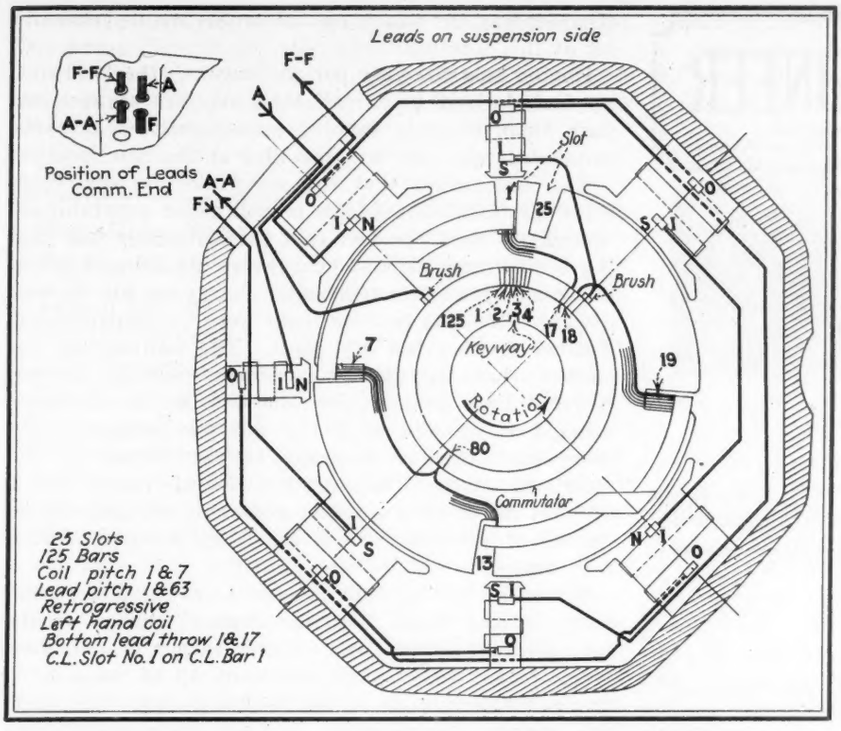


Fig. 7—This form gives all of the electrical connections in the motor.

Not only are the complete armature data given and the winding shown for a series of two coils, but also all of the series field, interpole field, brush, and terminal connections are shown. The starting coil is taken as starting from bar *18*. As can be seen a winding unit consisting of five coils per cell is used. *I* and *O* represent inside and outside terminals of the fields. The inside terminal is the one nearest the air gap. *N* and *S* indicate the polarity of the field poles. *A* and *A-A* are the terminals for the armature circuit which, of course, includes the interpole field. *F* and *F-F* are the terminals of the series field circuit.

which are called bottom straight coils. This term is used to denote that the commutator lead ends leave the armature slot and go to the commutator necks without dipping or bending down and up. There are also 15 bent bottom coils. The term bent indicates that the commutator end of the coils drops below the straight bottom coil, as the bent coil leaves the slot, then bends up again as it enters the commutator neck. The reason for the two kinds of bottom coil sides lies in the long bottom lead throw and the small amount of winding room between the armature core and the commutator, which requires the bottom leads to be put down in two layers.

The upper right-hand diagram in Fig. 6 shows the slots in which the straight and bent coils fall. The inner circle represents the bent coils while the outer circle represents the straight coils.

Inspection of the lower right-hand diagram of Fig. 6 will show that top lead *1* is connected at the rear of the armature to bottom lead *3*; that is, there is a "creepage" of two straps. Likewise top leads *4* and *5* connect at the rear to bottom leads *2* and *3*, respectively. The data in Fig. 6 also indicates that the winding uses right-hand coils.

Fig. 7 shows an extremely elaborate type of data sheet which gives the field connections, the brush position, the direction of rotation of the armature, and the polarity of the interpoles in relation to the polarity of the main field poles, as well as the layout of the armature winding. As can be seen, the first coil starts at commutator bar *18*, goes to slot *19*, through this slot to slot *13*, and thence to commutator bar *80*. The second coil starts at commutator bar *80* and goes to slot *7*, through slot *7* to slot *1*, and thence to commutator bar *17*, one bar behind the starting point. Consequently, the winding is retrogressive.

Inspection of slots *1* and *7* will show that the winding has five coils per cell. Notice that the winding is laid off from the center coil in the cell. Also note that commutator bar *1* is taken as the bar which falls on the center line from slot *1*. Commutator bar *3* falls over the center of the keyway. These data thus locate the position of the core and commutator with respect to each other and to the keyway of the shaft.

All of the connections of the series and interpole fields are given. The polarity of each pole is indicated by *N* or *S* placed on each pole.

The order in which the leads are brought outside of the frame is shown in the small diagram in the upper left-hand corner of Fig. 7. Careful study of this form of diagram will show that all of the electrical connections in the motor are given, as well as the electrical relationship between the various parts.

Succeeding articles in this series will take up in detail the methods used to obtain the winding data and will give rules for the guidance of the winder in taking these data.

Making a Survey of the Power Load

(Continued from page 315)

motor and thus make it run at leading power factor.

The reactive kilovolt-amperes taken by the load shown at *BO* are equal to *BF* or 1,393 kva. This must be reduced by an amount that will bring the system power factor up to 90 per cent as that is the power factor desired. Draw the 90 per cent power factor line, *MO*. *MO* intersects *BF* at *C*. Hence at the desired 90 per cent power factor the system will draw a reactive kva. equal to *CF* or 821 kva. The synchronous motor must therefore supply a leading reactive kva. of *BC* or 572 kva. as well as a true power of *AB* or 642 kw. Hence the capacity of the synchronous motor is represented by *AC* and is equal to 860 kva. It will operate at 74.6 per cent leading power factor. The system load is now represented by *OC* and scaling the graph we find it equal to 1,888 kva., which is well within the 2,000 kva. rating of the generators.

A summary of the new conditions shows the following:

(1) The load on the alternator is reduced 2,510—1,888=622 kva.

(2) The load in kilowatts is reduced by 1,728—1,700=28 kw.

(3) The reactive kilovolt-amperes are reduced by 1,820—821=999 kva.

(4) The power factor is increased from 68.8 to 90 per cent lagging.

The change thus eliminated the necessity of an additional alternator with its prime mover, extra switching equipment, cables and additional floor space, and thus decreased the cost of operation, and improved voltage regulation and operation of each individual induction motor.

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

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Chicago, July, 1925

Why Wait for Belt Trouble to Happen?

BELT trouble on important drives, or any other interruptions to the operation of equipment, always seem to happen when the shop is busiest. It is, however, only natural that the belt should give way when it is called upon to perform its hardest service; it would hardly be expected to fail under light operation or when the shop is shut down.

One operating engineer solved this problem by deciding that instead of waiting until belts stop work because they are dirty, dry, or need tightening, which is more his fault than the belt's, he would, at least once a year, take them down when work was slack or the shop closed and clean them thoroughly, re-oil them and put them back into service with a newly cemented joint. Since this policy of annually going over all belts on important drives has been in practice, no group drive belt has failed in service. It takes time to do a good repair job, and time is mighty scarce when the men on a group of machines are idle because of a breakdown.

The policy of avoiding difficulties instead of overcoming them, seldom, if ever, fails to pay big dividends.

A Load Survey That Was Worth $10,000 a Year

NOT SO very long ago a load survey was undertaken in a large industrial plant. One of the conditions brought to light was quite startling and resulted in a saving of $10,000 a year.

This plant was somewhat like Topsy—"It just grew." In its earlier days, direct-current power was secured by the use of steam-driven generators. When the demand for power became too great for these machines, it was decided to get the additional power from the local central station. Accordingly, a 25-cycle motor-generator set was installed to take care of this requirement. Five years later, due to plant extensions, a large amount of direct-current power was required at the other end of the plant, which is about half a mile away. The cheapest way out was to put in another motor-generator set at this location.

During this five-year period, however, the local utility had decided to curtail their 25-cycle service and push their 60-cycle supply; consequently, a 60-cycle, motor-generator set was installed at the new location.

The load survey that was undertaken several years after the installation of the second motor-generator set brought to light the fact that this consumer was paying a maximum demand charge for his 25-cycle power and another maximum demand charge on his 60-cycle power. This was because there were two separate and distinct services for this plant. The load survey also showed that the maximum demand on the 25-cycle power did not occur at the same time as the maximum demand on the 60-cycle power. It was estimated that there was sufficient diversity between these two demands to warrant replacing the 25-cycle motor with a 60-cycle motor on one motor-generator set and obtaining all of the power from the 60-cycle supply. This was done.

When the monthly bill came in from the power company, it was found that the demand charge on the new 60-cycle service was scarcely larger than before, which meant a saving of practically all of the demand charge formerly made on the 25-cycle power. Of course, the energy charge billed against the company was equal to the sum of the old 25-cycle and the old 60-cycle energy charges.

The saving in this case amounted to $10,000 a year. This investigation of diversity factor was decidedly worth while. On page 310 of this issue, Mr. Stafford gives the elements of a load survey and the methods of making one. If you are interested in cutting power costs in your plant, a perusal of this article will be well worth the time spent.

Make Conditions Justify the Use of Special Equipment

THE use of equipment which is specially designed and built is oftentimes justified by the service conditions that must be met. Nevertheless, this is a question that should be considered very carefully before a decision is made to use other than standard equipment. There are several reasons for this.

In the first place the cost of special equipment is necessarily high, as a good deal of engineering and designing work may be needed and the cost of this must be, at least in part, charged against a comparatively small number of units instead of spread over a large number of units in quantity production, as in the case of standard apparatus. In addition, much of the work may, in the absence of the proper jigs and fixtures, have to be done by hand, which means considerably reduced output; more supervision is required, and there is likely to be greater spoilage and wasting of material.

Furthermore, although the equipment may have been designed with the utmost care there is always the chance that the searching test of service may reveal hidden defects or weaknesses that would probably not be present in standard equipment, whose design has been perfected through the experience gained in watching the equipment under service conditions.

The possible difficulty and expense of getting repairs made and obtaining spare parts is another matter that

should be considered in connection with the use of equipment that is not standard.

Special equipment has its place, but as a general proposition that place is not in any application where standard equipment can be used.

How Many Tons Do You Handle per Ton of Output?

MARK TWAIN is credited with the remark, "Many people talk about the weather but they don't do anything about it." The same could probably be said of the material-handling problem in many industrial plants. In those plants where the cost of handling material is lumped under "indirect labor costs," this item of expense is considered a nuisance but, when grouped this way comparatively little can be done about it, as usually many other items of expense are included.

Material-handling problems will be but little understood until it is generally realized how extensive they are in industrial processes and also exactly what they cost. Some few years ago the chief engineer of a large midwestern foundry investigated and found that to produce one ton of miscellaneous castings of small size, averaging a few pounds each, required that 168 tons of pig, scrap, flasks, debris, castings and other materials must be handled. Startling as this figure may seem his foundry was very well organized, and investigation showed that many other plants were handling almost twice as much material to get out the same amount of work. This was due to an excessive amount of unnecessary rehandling.

The first step in any work of this sort is to find out exactly how many handlings are made and how much they cost, together with exactly how they are done. The next analysis is to determine how many of these handlings are unnecessary or can be combined with others. After that, it is merely a question of the most effective equipment for the work. These are steps which may be taken in practically any plant and will pay big dividends on the time spent in the investigation. A careful investigation may show you how to do something much more effective than merely talking about your material-handling problems.

Overvoltage on Lamps Means Short Life

A RECENT incident in a large plant brings to mind a subject which ought to be well known, but is not always given the attention that it deserves.

In one department of the plant mentioned, considerable concern was felt because of the change in the life of the incandescent lamps that were being used. Careful investigation was made to see if these lamps were being subjected to unusual vibration or other abuse. It was found that 125 volts alternating current was being supplied to the lamps in question and that these lamps were rated at 115 volts. Further investigation disclosed that 120-volt lamps had been requisitioned, but that the purchasing department had taken it upon themselves to change this to 115 volts, simply because there were no 120-volt lamps in stock at the supply house at the time the lamps were ordered.

The evil effect of operating lamps on overvoltage ought to be well known. In this case, there was an overvoltage of 8.7 per cent which brought the average life per lamp down to 30 per cent of normal. Ordinarily, 120-volt lamps were used on this supply, but even in this case the lamps are operating at 4.16 per cent overvoltage, which gives an average lamp life of about 56 per cent of normal.

The average life of a standard Mazda multiple lamp is said to be 1,000 hr. When using 115-volt lamps, the plant mentioned was getting an average lamp life of only 300 hr. or 25 nights' use of the lamps, whereas by using 125-volt lamps or reducing the lighting voltage to 115 volts they could have expected 1,000 hr. or about three months' life from their lamps.

This incident should point out the value of making a survey of the voltage delivered at the lamp sockets in all parts of your plant and seeing that the proper lamps are used. This survey should be repeated at regular intervals, for load changes or other conditions may affect the voltage.

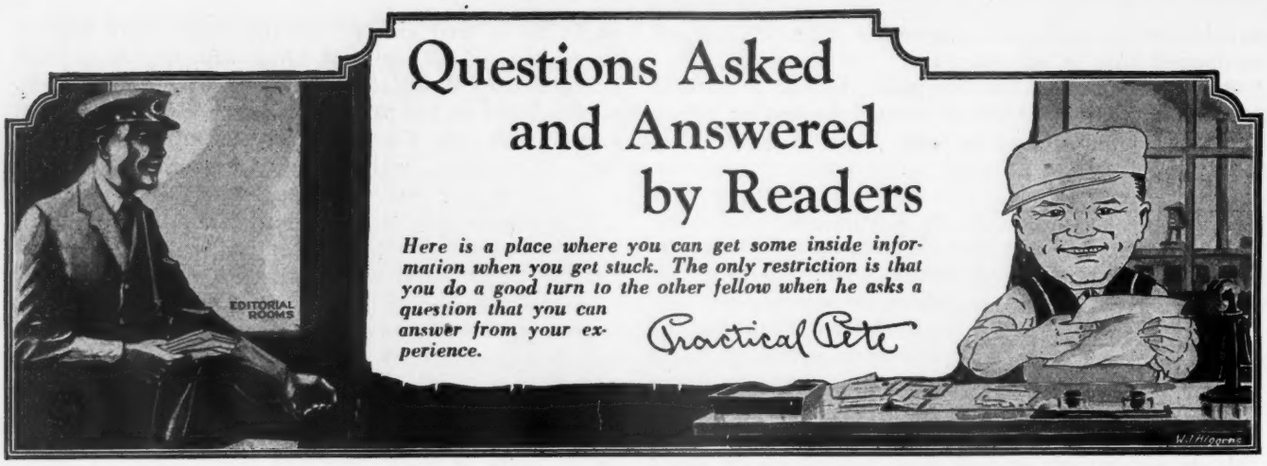
Money saved on lamp renewals is just as good as money saved in any other way, and it doesn't cost much to find out how much you can save.

A Study of Your Repair Work May Save You Money

ONE of the problems confronting every medium-sized or large industrial plant is to determine how far the maintenance department should go in doing its repair work and what work is to be sent out to be done. Most industrial men have learned by experience and careful comparison of costs that it usually pays to keep on hand a small stock of parts purchased from the manufacturer, such as bearings and other similar parts, which may be expected to wear out more or less frequently.

The question of whether to rewind motors and make extensive repairs to such devices as commutators is often open to discussion. Usually, the decision depends upon the quantity of work to be done, the outside agencies available and whether any of it is of an emergency nature. One plant with enough winding work to keep a man busy was not satisfied that it could do this work to the best advantage, and made a further analysis of its repair jobs. Here, as in most cases, the decision to do this work in the plant had been made because it was felt best to have a repairman on hand for emergency work on special motors, such as those direct-connected to some machines for which no spare motors were available. An analysis of repair jobs showed that these emergency cases occurred only a few times a year and that they practically always meant overtime work for the winder.

Arrangements were made with a local repair shop to rush these special motors as emergency jobs and put as many men on the job as feasible. Ordinary repairs on motors for which spares are available are handled in the plant repair shop, according to the regular routine, which delivers the motor within a fixed period. This relieves the maintenance department of carrying considerable repair stock and also releases some floor space which is badly needed. Perhaps, it would pay other plants to make a similar analysis of equipment failures, to determine how the repair work can best be handled.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

Who Can Answer These?

Bull Ring for Gas Pump—Can some reader give me any suggestions on how to make a bull ring for the piston of a gas pump having a cylinder diameter of 36.25 in.? In making the ring, what is the allowance in diameter to provide the necessary "spring" to hold the ring tight against the cylinder wall? Also, what is the best type of joint to make in the ring?
Paulding, Ohio. J. G.

* * * *

Use of Armored, Lead-Sheath Conductor Underground—Will some of the readers of INDUSTRIAL ENGINEER please give me their experience with the use of 2,500-volt, lead-encased, steel-wound wire such as is put out by some of the large manufacturers and intended to be used underground, and not protected by conduit?
San Diego, Calif. W. P. B.

* * * *

Method of Cleaning Motor Winding—What is the best method of cleaning motors that are oil-soaked and dirty? Can they be washed in gasoline and baked out in a bake oven to any advantage? What is the best method of handling the gasoline? Should the armatures be dipped in a trough containing gasoline, or should they be wiped with a gasoline-soaked rag? I would greatly appreciate hearing of any other methods used by readers for cleaning oil-soaked windings, as well as the results obtained by using gasoline for cleaning.
Chicago, Ill. R. W. A.

* * * *

Mounting Motors on Ceiling—In order to get more free floor space we are planning on mounting the motors on the ceiling, above the machines and lineshafts which they drive. I should like to have the experiences of other readers on the following points: (1) The best method of attaching motors to concrete ceilings. (2) What is the best and simplest method of raising and holding motors up until they can be attached? (3) Is there likely to be any more trouble with motors so mounted, than when they are placed on the floor?
St. Louis, Mo. E. H. G.

* * * *

Method of Removing Cores from Fan Motors—Will some reader tell me the best method and equipment to use for removing the cores from 10-in., 12-in., and 16-in. Westinghouse fan motors? I find it necessary to remove these cores from the drawn steel housing that encloses the motor so as to be able to make repairs on the connecting wires, which usually burn off very close to the housing. This connection cannot be made on the outside. These field cores fit so closely that it is almost impossible to remove them without injury to the windings with all the methods that I have tried so far.
Madisonville, Ky. E. F. L.

What Causes These Brushes to Chatter?—I have a three-phase, 440-volt,70 hp., slip-ring motor which is giving trouble from chattering of the brushes. Everything that I know of has been tried to prevent this, but without success. The brushes will stop chattering immediately after the slip rings are sanded slightly while the machine is in operation. But after several hours they begin to chatter again. I shall appreciate it very much if some of the readers of INDUSTRIAL ENGINEER will tell me how I can overcome this trouble.
Los Angeles, Calif. F. P. B.

* * * *

Emergency Excitation for Generators—For exciting our generators we have one motor-driven exciter which is normally in use. After the station has been completely shut down, we have one steam-turbine-driven exciter which is used for starting. Suppose that when we attempt to start up, the steam-driven exciter should break down. How could we excite our field? Could it be done by using several automobile storage batteries in series? For exciting our generator at no load, we require 60 amp. at 65 volts and it would be necessary for this supply to be on for approximately 10 min. Would it be practicable to use eleven 6-volt storage batteries in series for supplying this excitation? If so, what capacity should the storage batteries have? I shall appreciate any information that readers can give me on this problem.
Medicine Hat, Alta., Can. E. R. S.

Answers Received To Questions Asked

Rewinding 110-Volt Generator for 6 Volts—I have a 110-volt, 0.25-kw., 2,000-r.p.m., shunt-wound generator and should like to know if it can be reconnected or rewound to give six or eight volts, for charging storage batteries. If so, will some reader please give me some information on the size of wire to use, number of turns and so on?
Allentown, Pa. A. H. S.

With reference to the question asked by A. H. S. in the May issue, he does not state the size of wire in the armature or field or give any data regarding the commutator segments. The present output of the generator is 0.25 kw. at 110 volts, which would be approximately 186 watts, with a current of 1.7 amp. To change this over so that 6- to 8-volt storage batteries could be charged, would necessitate rewinding the armature and fields for 12 volts. Assuming that the output would be the same as on 110 volts, the wire in the armature would have to carry approximately 15.5 amp. It is doubtful whether the commutator segments would handle the current without giving trouble. Also, the brushes and brush holders would have to be remodeled.

A. H. S. can determine the present size of wire and count the number of turns in the field and the number of turns per armature slot. In rewinding the armature and field coils, decrease the number of turns approximately in the ratio to the decrease in voltage; that is, in the ratio of 110 to 12. Also, increase in the size of wire so as to enable it to carry 15.5 amp.

This is a rough method, but with the data at hand this is all the information I can give. I might state, however, that I do not think it practicable to change this machine over for the low operating voltage.

Chief Electrician, WILLIAM B. CONE.
Shevlin-Hixon Co.,
Bend, Ore.

* * * *

Operating Motors in Parallel on Bridge Motion of Crane—Two series motors are used to drive the bridge motion of one of our cranes. Each motor drives one set of track wheels, so that the two motors are practically operating in parallel. They are controlled by two contactor panels operated from one master switch. With this combination the armature burnouts were so frequent that it was decided to connect the armatures of the two motors in series and the fields in parallel. As we still had burnouts it was decided to connect the armatures and fields all in series. This has eliminated a great deal of the trouble, but it reduces the speed of the bridge.

I would like to know what is the cause of the trouble that I have been experiencing. Can some reader suggest a method of connection that will eliminate the trouble from burnouts and at the same time give normal speed on the motors?
Indiana Harbor, Ind. A. R. D.

With reference to A. R. D.'s question in the May issue, the two motors on the crane bridge might to great advantage be connected with the armature of each in series with the field of the other. This arrangement would bring the motor speed up to normal and also would make an equal division of the load between the two motors. It is understood that one controller is now used for the two motors. If this is not the case, it is believed that such an arrangement should be made, as then each motor would be working under the same conditions at all times. The control equipment and wiring on the bridge would be reduced almost 50 per

cent by using only one controller. Likewise, the expense for spare parts for the controller would be reduced in the same proportion, while the probable time lost by the crane due to electrical trouble with the bridge equipment would be reduced by more than 50 per cent.

D. W. BLAKESLEE.
Electrical Engineer,
Jones & Laughlin Steel Corp.,
Pittsburgh, Pa.

* * * *

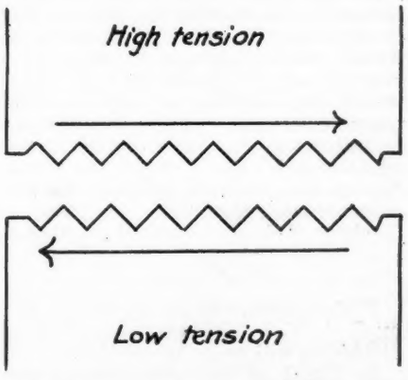
In answer to A. R. D. in the May issue, I would say that his second method of connecting the two motors in parallel is correct. I would suggest that he check up on the control, and check the fields for roasted coils, partial shorts, and polarity. Then if the motors appear to be all right, make ammeter tests on both motors to see whether or not the motors are overloaded. Also, make sure that the crane is in good condition mechanically.

We recently had a series motor on the trolley of one of our large cranes which gave us considerable trouble. The armature drew an abnormally large amount of current, sparked badly at the brushes, and finally burned out the armature. On taking the motor apart, we found that it had been running for some time with some of the poles having incorrect polarity.

Detroit, Mich. A. J. CONWAY.

* * * *

Polarity of Transformer—After reading the article on "Checking and Testing Transformer Connections" on page 560 of the December, 1924, issue of INDUSTRIAL ENGINEER, I am somewhat confused as to the relationship between the primary and secondary voltages for transformers of different polarities. Assume a transformer having primary and secondary voltages in the winding as shown by the arrows in the diagram. Can some reader tell me whether this transformer has additive or subtractive polarity, and why?



Chicago, Ill. G. A. V.

In reply to the first part of the question asked by G. A. V. in a recent issue, the whole trouble and misunderstanding are due to the fact that not enough attention has been given to the terminal markings of the diagram and too much attention and weight have been given to the arrows without understanding what they mean. In fact, it might be better to eliminate the arrows entirely as they seem to be the cause of all the misunderstanding regarding the polarity.

Disregard the arrows for the moment and you will see that Figs. 1 and 2 on page 561 of INDUSTRIAL ENGINEER, and which are shown in the accompanying diagrams, are correctly marked for subtractive polarity and additive polarity, respectively, in accordance with the definition of polarity as given in Electric Power Club rule 9077 and in accordance with rules 5407, 5411 and 5412. The latter three rules cover the marking of the leads.

Rule 5412 states that the numbering of leads shall be so applied that when H_1 and X_1 are connected together, and voltage applied to the transformer, the voltage between the highest numbered H lead and the highest numbered X lead shall be less than the voltage of the full high-voltage winding. From this it will be seen that the voltmeter in Fig. 1 must read less than the voltage of the highest voltage winding. By the definition given in rule 9077, this makes the transformer have subtractive polarity. For the same reason, the voltmeter in Fig. 2 must read more than the voltage in the high-voltage winding, making its polarity additive. These requirements for additive and substractive polarity are not affected by any arbitrary use of undefined arrows.

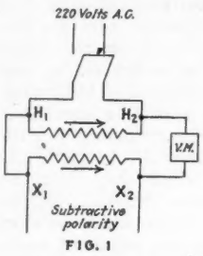


FIG. 1

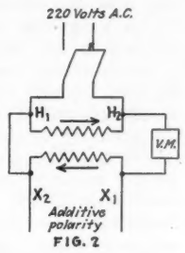


FIG. 2

Methods of testing transformers for polarity.

In Fig. 1 two adjacent high-and low-tension terminals, H_1 and X_1 are connected together and a voltmeter is connected to the other two adjacent terminals, H_2 and X_2. The 220-volt, alternating-current power is applied to the high-tension winding as shown. If the voltage measured on the voltmeter is less than the voltage applied to the high-tension winding the transformer has subtractive polarity, as shown in Fig. 1. If the voltage reading is greater than the supply voltage, the transformer has additive polarity, as shown in Fig. 2.

If arrows are used at all, they should, to be consistent, have the same meaning in both primary and secondary windings. In other words, they should both point either from or toward the highest numbered lead in both cases and this condition will be fulfilled if the arrows are assumed to represent induced voltages in both windings. This will not only prove consistent with the rules already mentioned for the numbering of the leads, but will also make the voltages in the case of interconnection between the two windings, add or subtract according to the arrows.

The arrows cannot represent induced voltage in the secondary and impressed voltage in the primary with the lead markings as shown.

Referring now to the latter part of the question asked by G. A. V., it is impossible to answer this as it stands, although the arrows are said to represent primary and secondary voltages. The question does not state whether these arrows represent induced or impressed voltages, nor does the diagram give any terminal markings. The diagram therefore, can be said to represent additive or subtractive polarity, depending upon what primary or secondary voltages the arrows are supposed to represent, or what terminal markings are given to the leads.

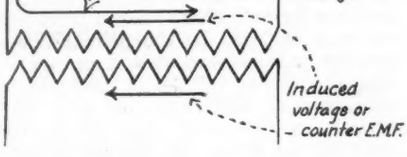
If arrows are to be used in the diagram, it is better to have them represent induced voltages in both the primary and secondary windings. This produces perfectly consistent diagrams in that both the direction of the arrows and the markings of the leads will agree. However, as I have stated before, it might be simpler to eliminate the arrows altogether and use just the terminal markings.

S. N. CLARKSON.
Executive Secretary,
The Electric Power Club,
Cleveland, Ohio.

* * * *

In reply to the question asked by G. A. V. in a recent issue the transformer has subtractive polarity if the high-tension voltage as shown in the diagram is the impressed or line voltage, and if the low-tension voltage is the induced voltage. On the other hand, if both arrows are taken as indicating induced voltages, then the polarity of the transformer is additive.

To make this clear I am showing the relation between the impressed or line voltage and the induced voltage, in the accompanying diagram. We know that when voltage is impressed on any coil, there is an induced or counter-voltage in opposition to the impressed voltage.



Relation between impressed and induced voltages.

The voltage impressed on the primary of the transformer causes a current to flow which generates a flux. This flux acts on both the primary and secondary windings and induces a voltage that is opposed to the impressed voltage.

This induced or counter-voltage is the same in both windings, since both windings enclose the same magnetic field. We believe that a good bit of the confusion regarding the question of polarity is due to the terms, *impressed* and *induced* voltage. When these are separated or specified the solution becomes simple.

J. B. HODTUM.
Western District Office,
Pittsburgh Transformer Co.,
Chicago, Ill.

* * * *

Answering the question by G. A. V. in a recent issue, the transformer shown in his sketch has subtractive polarity if the arrows are taken as representing the instantaneous direction of current in the primary and secondary windings. Granting that the arrow

on the primary winding indicates the direction of the impressed current and likewise the direction of the impressed voltage, then the arrow on the secondary winding would show the direction of the induced current and induced voltage. In the case shown in G. A. V.'s diagram, these arrows are opposed to each other; consequently, if the left-hand, high-tension and low-tension leads be connected together and a voltmeter connected across the right-hand, low-tension and high-tension leads, and at the same time the high-tension winding be excited, the voltmeter will read the difference in the two voltages and since this would be less than the value of the impressed primary voltage, the transformer would have subtractive polarity.

ERNEST DICKINSON.
Kimberley, B. C., Can.

* * * *

In the question asked by G. A. V. is shown a diagram indicating a transformer having additive polarity. The usual method for testing this is very clearly indicated in Mr. Staubitz's excellent article in the December issue of INDUSTRIAL ENGINEER, where he explains the diagrams on page 561. Additional explanation going further into the details of what actually happens in the transformer winding may also be helpful.

In an alternating-current circuit, the voltage is zero at one instant, then increases to full value in the positive direction, reverses and falls to zero, increases in the negative direction and then falls to zero again. There are 60 of these complete cycles per second in a 60-cycle circuit. Whenever the voltage increases in one direction or the other, lines of magneto-motive force are caused to increase in the iron of the transformer. These lines of force are not only enclosed by the primary coil, but also by the secondary coil and therefore an induced voltage is produced in the turns of both windings and both will be in the same direction at the same time. Since the voltage is constantly changing in this manner, we will consider the conditions existing in the transformers at one particular instant.

Assume that at a certain instant, voltage is impressed in the primary of a transformer. This causes a magnetic flux in the transformer iron as indicated by the dotted-line arrows in the iron of the transformers in the accompanying diagrams, *A*, *B*, *C*, and *D*.

It should be noted that the voltage arrows which represent induced voltages in the windings will all take the same direction because the voltages in both the primary and secondary windings are induced by the same flux. This holds good whether the secondary is wound counter-clockwise as in transformers *A* and *B*, or clockwise as in transformers *C* and *D*. An inspection of the method of winding these transformers will indicate that this does not affect the polarity. The polarity is determined entirely by the way in which the transformer leads are brought out of the transformer tanks. According to the A. I. E. E. standards "the polarity of a transformer is subtractive when H_1 and X_1 are adjacent, and additive when H_1 is located diagonally across from X_1."

Furthermore, the rules state that "the H_1 lead should be brought out at the right-hand side of the case when facing the high-voltage side of the case." Transformers *A*, *B*, *C* and *D* all have the H_1 lead so located. All of these transformers have the primary windings, wound counter-clockwise. Transformer *A* has its secondary winding also wound counter-clockwise and by making the voltmeter test as described in Mr. Staubitz's article (that is, connecting two adjacent leads, say H_1 and X_1, and connecting a voltmeter across H_2 and X_2), it will be seen that the polarity of this transformer is subtractive. Transformer *B*, however, is wound exactly the same way, but the secondary leads are crossed before bringing them out of the tank, so that connecting the same two adjacent leads we get H_1 and X_2 connected together and the voltmeter test shows this transformer to have additive polarity. In order to make this transformer operate in parallel with transformer *A*, it is therefore necessary to cross the leads again, when connecting it in parallel with transformer *A*. Transformer *C*, although it has the secondary wound exactly opposite to transformer *A*, is made to have subtractive polarity the same as transformer *A*, by crossing the leads before bringing them out of the tank. Transformer *D* has its secondary wound exactly the same as transformer *C*, but because the leads were not crossed before bringing them out of the tank, it will be necessary to reverse them afterwards in order to have this transformer operate in parallel with the other three transformers. However, since the polarity of a transformer is determined entirely by the way the leads are brought out, its polarity is opposite to that of *C*.

These transformers are correctly connected for parallel operation, although they are of different polarities caused either by the primary and secondary windings being wound in opposite directions or by crossing the secondary leads within the transformer case.

If the leads on any one of the four transformers shown were arranged so that its X_1 lead was connected to the same bus as the X_2 leads of the other transformers, and its X_2 lead connected to the same bus as the X_1 leads of the other transformers, there would be a surge of current through the secondary windings which would cause fuses to blow or circuit breakers to open.

ROGER F. EMERSON.
Industrial Engineering Dept.,
General Electric Co.,
Schenectady, N. Y.

* * * *

In reply to the question asked by G. A. V. in a recent issue, I would say that the polarity of the transformer shown in the diagram is additive. I would refer you to the definition of polarity given by the American Institute of Electrical Engineers, which is as follows:

"If the primary and secondary windings have a relation such that the two leads nearest each other can be joined together and the voltage across the two windings is greater than the voltage of the high-tension winding, then the polarity is additive or increasing. If less, the polarity is subtractive or decreasing."

THOS. M. HUNTER.
American Transformer Co.,
Newark, N. J.

* * * *

In reply to the question asked by G. A. V. in a recent issue, I would say that a transformer having the characteristics as outlined in his diagram has additive polarity. A transformer having subtractive polarity has its secondary so connected that the induced current opposes or bucks the current of the primary. In other words, the currents act against each other in the same way that two streams of water would should they be turned against each other. When the transformer has additive polarity the two currents work together.

Riverside, Cal. PHIL D. COMER.

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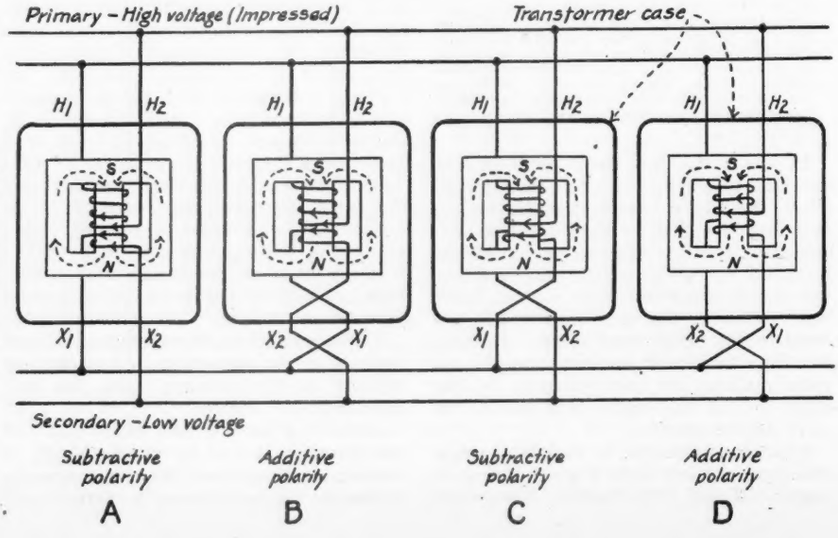
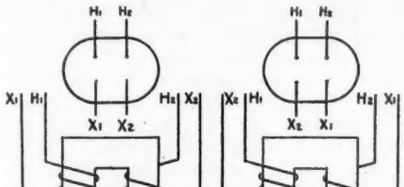
With reference to the question asked by G. A. V. I think that the following discussion will solve his problem.

In Fig. 1 of the accompanying dia-



gram, the high-voltage and low-voltage sides of the transformer are wound in the same direction, assuming that H_1 and X_1 are the starting points.

In order to prevent confusion it is advisable to neglect current and think only in terms of induced voltages. Since the same flux induces both the high and low induced voltages, they must be in the same direction in each turn. However, whether they will appear in the same or opposite directions as viewed from the terminals depends upon the relative direction of the winding. Thus, in Fig. 1, voltages H_1H_2 and X_1X_2 are in the same direction and in Fig. 2 voltages H_1H_2 and X_2X_1 are in opposite directions. If we take the order of lettering to indicate the direction of the induced voltage, then in Fig. 1 voltages H_1H_2 and X_1X_2 are in the same direction and in Fig. 2 voltages H_1H_2 and X_2X_1 are in opposite directions.



Figs. 1 and 2—Polarity is the relative direction of the induced voltage from H_1 to H_2 as compared with that from X_1 to X_2.

When the induced voltages of the high- and low-voltage sides are in the same direction, as in Fig. 1, the polarity is subtractive and when the induced voltages are in opposite directions, as in Fig. 2, the polarity is additive.

Referring to the tank sketches at the top of Figs. 1 and 2, polarity is the relative direction of induced voltage from H_1 to H_2 as compared with that from X_1 to X_2. When the induced voltages of the high- and low-voltage sides are in the same direction, as shown in Fig. 1, the polarity is subtractive and when the induced voltages are in the opposite directions, as shown in Fig. 2, the polarity is additive.

M. F. MITSCHRICH.
Moloney Electric Co.,
St. Louis, Mo.

* * * *

In reply to the query of G. A. V. in a recent issue, I find the following a very easy way to remember the relative polarity of transformers. My method is to follow the polarity arrows on both the primary and secondary sides right through. If they help each other (add to each other) the transformer is of additive polarity. In other words, in the diagram given by G. A. V., if he will start at the left-hand side of the high-tension winding and follow through the winding in the direction of the arrow and then go down to the adjacent low-tension side at the right and go through this winding, he will find that he will have traveled through both windings in the same direction as the arrows indicated. On the other hand, however, if one of the arrows is opposed to this direction of travel, then the transformer is thought of as being subtractive. This is a very easy way to remember the polarity.

EDWIN W. LINDOP.
Service Department,
General Electric Co.,
Los Angeles, Cal.

* * * *

Using Vacuum Pump as Air Compressor—I have a Wahl vacuum pump, size 4 in. by 2½ in., with ¾-in. inlet and outlet, which I wish to use as an air compressor. The pressure in the air tank need not go over 125 lb. per sq. in. Will someone please tell me, (1) What size motor would be required to drive this pump at 275 r.p.m. (2) Will it be necessary to make provision for cooling this pump artificially, by means of air fins or water, in order to keep the temperature down to a safe limit? (3) How do you figure the cubic inches of air compressed per stroke?
Dallas, Tex. R. E. L.

In the May issue are answers by R. A. Kiefer and E. H. Laabs to a question by R. E. L. on the practicability of using a 4-in. by 2½-in. vacuum pump as an air compressor to work under a pressure of 125 lb. per sq. in. Mr. Kiefer condemns the idea because, he thinks, the cylinder is not strong enough to stand a pressure of 125 lb.

The formula for the required thickness of a cylinder subjected to internal pressure is $t=(P\times d)\div(2\times S)$, in which t is the thickness of cylinder wall in inches, P the pressure per sq. in., d is the bore of the cylinder in inches and S the working strength of the material.

In the case that was under discussion, with $P=125$ lb., $d=4$ in., and S (cast-iron)$=2{,}500$ lb., the required thickness is $t=(125\times4)\div(2\times2{,}500)=0.1$ in. Surely, the cylinder wall is 0.1 in. in thickness! Because of practical considerations, the thickness of the wall of the cylinder of R. E. L.'s vacuum pump is probably not less than 0.5 in.; so it would seem that strength is not an important consideration.

In figuring the capacity of the compressor, Mr. Laabs evidently assumes 100 per cent volumetric efficiency. A compressor of the size under discussion would probably have a volumetric efficiency of about 75 per cent; so the capacity at 275 r.p.m. would be (assuming a single-acting machine) 3.75 cu. ft. free air per minute.

Single-stage compression to 125 lb. is not considered good practice because it is less efficient than two-stage compression and, worse still, produces a temperature that is destructive to lubricating oil. The adiabatic temperature of air compressed to 125 lb. gage, is above 500 deg. F.; so any system of cooling that R. E. L. succeeds in applying to this compressor will probably not prevent some trouble in maintaining lubrication.

The reason for reducing the size of outlet from ¾ in. to a ⅜-in. or ¼-in. check-valve, as recommended by Mr. Laabs, is not clear. The only effect that this reduction would have would be a slight restriction to the flow of the air—and perhaps lower cost of valves and fittings.

C. O. SANDSTROM.
Los Angeles, Cal.

Trouble With Rewound Automobile Generators—I have been rewinding some automobile generators, but in spite of the fact that I always check up the old winding and make the new one as nearly like it as possible I sometimes have trouble in getting the proper amperage out of the generator. The voltage will be up to normal, six volts, but the charging rate is too low. I wish some reader who has had experience in such work would give me some suggestions as to where the trouble may be.
Bathurst, N. B., Can. H. J. M.

In answer to H. J. M.'s question in the March issue, I believe that his trouble is due to improper connection of the leads to the commutator. From his description it would appear that the leads have been dropped back too far, that is, dropped in the direction of rotation. All automobile generators are driven in the same direction as the engine turns and the third brush is adjusted in the direction of rotation to increase the amperage or output. If the leads come to the commutator one bar ahead of the place where they were in the original winding, the output may be cut down. On the other hand, if they are put in the commutator one bar behind the original position, the output will be increased and the third brush must be moved opposite to the direction of rotation to cut down the output. Changing the third brush a fraction of an inch will sometimes change the charging rate 8 or 10 amp.

It is also quite possible that H. J. M.'s trouble is due to weak field coils as these will keep the charging rate down, especially if they are old and oil-soaked.

B. BELCHER.
Albany, Ga.

* * * *

Thickness of Mica Required for Slot Insulation—Will some reader please tell me what thickness of mica should be used to replace one layer of 0.007- or 0.010-in. varnished cambric and one layer of 0.007- or 0.010-in. fishpaper for slot insulation?
St. Louis, Mo. L. C. R.

In answer to L. C. R. in the March issue, the thickness of any slot replacement insulation depends not only upon the dielectric strength of the insulation but upon the thickness of the original and of the replacement insulation. Naturally, less mica insulation will be required for a given dielectric equivalent than when varnished cambric and fishpaper are used, but if no more than the dielectric equivalent is used the coil will be loose in the slot and subject to vibration with ultimate breakdown.

Authorities differ considerably on the dielectric strength of materials. For general reference, however, the following values may be used:

Varnished cambric, 1,000 volts per mil. Fishpaper, 200 volts per mil.

The dielectric strength of mica varies from 2,000 volts for 2- and 3-mil amber mica to 4,000 volts for ruby mica.

EDWARD JAMES.
West Allis, Wis.

* * * *

In answer to L. C. R.'s question in the March issue, he does not state what type of motor, that is, d. c. or a. c., or whether open or partly-closed slots are referred to. In the case of open slots, on either d. c. or a. c. machines, the following information may be of help to him.

One thickness of 0.015-in. or 0.020-

in. molding mica (Westinghouse No. 251 mica plate) can be cut the right width to suit the depth of the slot and a trough cut in a piece of hard wood which is the same width and depth as the slot and slightly longer than the core. Then cut a piece of wood the correct size to act as the male part of the mold, heat the mica plate and form it in the above mold, keeping it under pressure until cold.

Or No. 240 cambric and mica can be used. This comes in sheets 25 in. by 52 in. and is 0.013 in. thick. It can be cut and applied like fishpaper, etc.

There is a grade of flexible mica, No. 237, that comes in sheets 24 in. by 36 in. and 0.005 in., 0.010 in., 0.015 in., 0.020 in. and $\frac{1}{32}$ in. thick. This material can be cut and applied cold like varnished cambric for coil cells, but for slot insulation a backing of fishpaper is required. I would suggest the following: 0.010-in. flexible mica between two pieces of 0.004-in. fishpaper. This will give mechanical protection to both sides of the mica cell.

For slot insulation to be applied to the coil, I would suggest one and one-half turns of 0.010-in., No. 237 flexible mica or one and one-half turns of 0.012-in. No. 232 mica and fishpaper.

Wilkinsburg, Pa. A. C. ROE.

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In answer to L. C. R. in the March issue, mica does not have sufficient mechanical strength to be used alone for slot insulation. It can, however, be used with a fishpaper backing. Fishpaper and mica glued together so as to form one sheet may be purchased. The standard thickness of this material is 0.012 in.

If you cannot obtain fishpaper and mica in this form, use fishpaper of the same thickness that was originally used in the slot and mica which is equal in thickness to the varnished cambric.

Boulder, Colo. RALPH MCKINNEY.

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In answer to L. C. R.'s question in the March issue, I would advise using all the available space that he will have in the slot after the removal of varnished cambric and fishpaper, for the mica. The additional thickness will enable the coils to stand the heat better and will also give a larger factor of safety in the winding.

Fishpaper tests at about 200 volts per mil thickness. A 7-mil paper would, or should, when dry, stand about 1,200 volts. This paper ordinarily has about 8 per cent moisture. If the moisture content is very high the paper is a very poor insulator.

Varnished cambric should stand from 500 to 1,000 volts per mil thickness, up to about 20 mils thickness. A 10-mil thickness of varnished cambric would, of course, stand a test of approximately 5,000 volts.

Amber mica tests about 2,000 volts per mil, and white or clear mica tests about 3,000 to 4,000 volts per mil thickness. Clear mica in its original state is not flexible enough to use for coil insulation. It can be cut to fit the slots for the side of the coil insulation, and a strip cut for the bottom, the width of the slot. Mica cloth or some similar flexible material should be used to insulate the coils. Slot insulation can also be formed of molding mica. As slot insulation these materials could not be rated at such high voltage as the tests indicate. From L. C. R.'s question I judge that the voltage is 220 or 440. Also the coils probably have some insulation, at least cotton tape which, when it is properly impregnated, will test about 1,000 volts per mil.

The table given below for slot insulation thickness is found in Prof. Stills' book "Principles of Electrical Design," published by McGraw-Hill Book Co. This table is for one side of slot only. These figures also apply to the thickness of the insulation to use between upper and lower coils in slots.

	Voltage	Insulation, Inches
D. c. machines up to	250	0.035
	500	0.045
	1,000	0.06
	1,500	0.075
A. c. machines up to	1,500	0.075
	2,000	0.080
	4,000	0.120
	8,000	0.190
	12,000	0.270

Birmingham, Ala. GRADY H. EMERSON.

* * * *

Connecting Commutator Leads of G. E. 25-Cycle Desk Fan Armatures—Will some reader please tell me the general layout of the coils and how the top and bottom leads are connected to the commutators of G. E., Type AOU, Form V2, 25-cycle desk fan armatures? I have rewound two different armatures without much success, for when the fan is connected across the line the armature rotates only very slowly, with the fan removed.

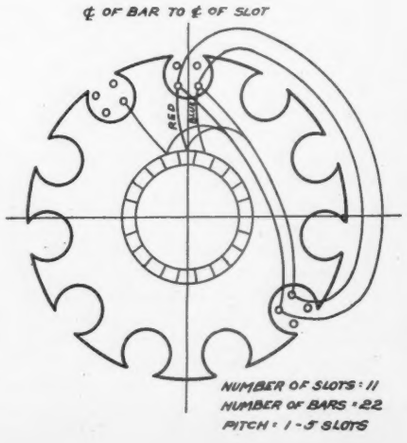
Phoenix, Ariz. F. R. S.

In the April issue F. R. S. asks for information on connecting a G. E. desk fan, Type AOU, form V2.

The accompanying connection diagram shows the coil throw and commutator connections. I trust this will give F. R. S. the information he desires.

Data Bureau, E. A. OTTO.
Pittsfield Division, General Electric Co.,
Pittsfield, Mass.

This diagram shows the coil throw and commutator connections of G. E., Type AOU, form V2 desk fan armatures.



How to Use Megger for Testing Insulation of Motors—I wish some reader would give me a few suggestions on the proper method of using a megger for testing the insulation resistance of motors. I should also like to know what is considered a satisfactory reading when testing 110/550 volt, a. c. and d. c. motors ranging from 5 hp. to 50 hp.

Latrobe, Pa. J. K. W.

Answering J. K. W. in the March issue, the manufacturer of the megger can give the best and most reliable information, but for general purposes, the following covers the necessary points to consider: In using a megger, connect the terminal marked "earth" to the frame of the machine to be tested; the other terminal should be connected to the line or coils of which the insulation resistance is to be tested. Turn the crank as rapidly as possible, and take the reading on the scale while the megger is running at its highest speed, which will be just before the clutch slips out.

The following formula can be used to check the results of the test and determine the condition of the insulation: Insulation resistance in megohms=machine voltage÷(rated kva.+1,000).

For example, a 2,200-volt motor rated at 1,500 kva. should have an insulation resistance of 880,000 ohms.

The formula given above applies only to dry apparatus. Such high values are not attainable in oil immersed apparatus. It must be borne in mind that these values apply only at operating temperatures. A motor measuring two megohms when cold will in general only show a fraction of a megohm at operating temperatures.

Chief Electrician, LEE F. DANN.
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

In reply to J. K. W. in the March issue, I would suggest that he, and any other readers who wish such information, write to James G. Biddle, 1211 Arch St., Philadelphia, Pa., whose advertisement appears on page 49 of the March issue of INDUSTRIAL ENGINEER, and ask for pocket manual 1060E which will give more information than it is possible to incorporate in a reasonable answer to this question. This booklet gives the A. I. E. E. and the Underwriters' regulations. The manufacturer of the motors can also furnish prints showing requirements for megger readings under various conditions.

For the benefit of those who are not interested in the publication mentioned above, a reading under one megohm is considered unsatisfactory. Readings on cold machines of the rating specified in the question may vary from 1 to 5 megohms. Temperature greatly affects the readings, the resistance decreasing with increase of temperature. When testing the machine should be "dead." Connect one line to ground from the proper side of the megger, as marked, and the other line to the conductor or portion to be tested. The crank should be turned not in excess of 120 r.p.m. About 500 volts will be generated at this speed; if the crank is turned at a higher rate of speed the insulation may be punctured. A direct reading of insulation resistance is shown on scale.

Tests can be made between phases

in the same manner by connecting lines from megger to phase leads. An important point to note in testing machines to ground is that lines from the machine may be the cause of poor readings. If doubt should arise in this matter the lines can be disconnected, the machines tested as units and the lines tested separately.

As stated before, readers will find it highly advisable to procure pocket manual 1060E or a similar manual from the maker of their instrument.

West Allis, Wis. EDWARD JAMES.

* * * *

In reply to J. K. W. in the March issue, the insulation resistance of low-voltage, up to 600 volts, a. c. or d. c. motors, should be as much as 1 to 5 megohms on a cold machine. When the machine warms up the insulation resistance will be lowered. When testing 110- or 220-volt machines, it is best not to turn the crank of the megger more than 120 r.p.m.

When cold, the resistance of high-voltage machines is about 90 to 100 megohms. One megohm is considered the limit of safe insulation resistance for low-voltage machines.

The values given above apply to motors up to 100-hp. rating. I hope that this information will be of some assistance to J. K. W.

Chief Electrician,
E. I. du Pont Co.,
Newark, N. J. H. CHARLTON.

* * * *

In answer to J. K. W. in the March issue, the megger should not be of too high range; a scale reading from 0 to 200 megohms is ample. With this scale readings as low as 10,000 ohms may be obtained. The megger should be placed on a level, solid support. The line wires should be connected to the winding to be tested and the ground or earth wire to the frame of the machine. These wires should be firmly fastened and not held in the hand. If the line wire is held in the hand, the reading will probably be the insulation resistance of the body to ground. If necessary, the wires may be supported by dry strings so that they will not touch each other, or any part of the machine except that to which they are attached.

When using the megger, do not try to bring up the speed too rapidly, or you may damage the instrument. Turn the handle at such a rate that the clutch slips. Continue at this speed until you obtain a constant reading. This will require only a few seconds for small motors, but may take a minute or more for large generators, due to their capacity. A slight shock may be received if the wire is removed before the generator in the megger has come to rest.

Any reading over one megohm is usually considered satisfactory for motors operating under 600 volts. If the motor is dirty or damp, it should be thoroughly cleaned and dried. Then test it again and keep a record. The motor should be tested at regular intervals and when the test shows a much lower reading than was obtained when the motor was known to be in good condition, it should be overhauled at once.

Boulder, Colo. RALPH MCKINNEY.

Rewinding Armature Increased Speed—I recently rewound the armature of a 100-hp., four-pole, shunt-wound, Northern motor and wish someone would tell me what is the matter with it. This armature had 110 bars and 55 slots and was wave-wound, with one dead coil and one half-idle bar. The coil pitch was 1-and-13 and the commutator pitch 1-and-56. When we rewound it one bar was taken out, which left 109 bars and one dead coil. I am not sure whether the commutator pitch was 1-and-56 or 1-and-55. When the armature was put back in the motor it ran at about 1,600 r.p.m., the commutator got hot and the bands threw solder, although the controller was on only the third point. I examined the field connections and took the voltage drop across each field coil; everything tested out OK. As a further check, a spare armature was put in this motor, and ran perfectly. Any suggestions you can give will be very welcome.

Wisconsin Rapids, Wis. W. B. L.

In answer to W. B. L.'s question in the April issue, I would suggest that he check up the span of his coils and see if he did not drop a slot. The commutator pitch on this armature should be 1-and-56. I know that in winding d. c. armatures if a slot is dropped in placing the coils in the armature, the motor will run up to or above normal speed on the first point of the rheostat. I recall one instance where one slot was dropped by mistake when rewinding the armature of a shunt-wound motor. When the motor was assembled, it ran above the speed given on the nameplate, when the controller was on the second point. The normal speed was 400-1,600 r.p.m., and the motor ran at 1,800 r.p.m on the second point. The field coils were checked for continuity and the pole pieces were removed to see that there was no rust or dirt under them. We finally wrote to the manufacturer asking for data on this machine and from his reply learned that the coils did not span enough slots. The armature was taken out and one side of the coils raised and spread to the next slot and the leads again laid down. After assembling this motor, it ran perfectly, showing clearly the cause of the trouble.

I hope that this experience will be of some benefit to W. B. L. and other readers of INDUSTRIAL ENGINEER.

Albany, Ga. B. BELCHER.

* * * *

In the April issue W. B. L. mentions the trouble which he has had with a 100-hp. armature that was rewound. The fact that one bar was left out would, if anything, tend to help the commutator. He says that there are 55 coils. The nearest correct span of coils would be 1-and-14 instead of 1-and-13. A throw of 1-and-13 comes out 1-13-25-37-49. A throw of 1-and-14 comes out 1-14-27-40-53, which is nearer to 55 than is 49. Possibly an error was made when the armature was stripped. When an armature from a four-pole machine has 109 bars and connects on the half, it could be connected either 1-and-55 or 1-and-56, the only difference being that a throw of 1-and-55 would cause the armature to run in the opposite direction to what it would with a throw of 1-and-56. A Northern motor is very sensitive to a slight shifting of the leads.

If the armature had originally been wound with a throw of 1-and-14 and then changed to 1-and-13, this would naturally cause a difference in the setting of the rocker arm. We once changed the throw of an armature with 61 coils from 1-and-16 to 1-and-15. When the armature was put back in the motor the commutator and the winding got excessively hot after a few minutes' running. The brushholder could not be shifted on this machine; so we had to connect the coils with a span of 1-and-16 again, after which the machine ran cool.

A motor can, of course, be speeded up somewhat, usually about 100 r.p.m., by shifting the rocker arm. W. B. L. does not say how much faster than normal the armature turns and it might be well to check the setting of the brushes as a possible source of the trouble.

Peoria, Ill. GEORGE D. RINGNESS.

* * * *

With reference to W. B. L.'s question in the April issue, I believe that if he will carefully check his lead throw, he will find that the leads are not connected to the commutator at the proper place for the brush setting. I would suggest that he check this point up very carefully.

The armature appears to be drawing an excessive current. From this circumstance, it would appear that a mistake may have also been made in the size of wire and number of turns used when rewinding this armature, and I believe it would be worth while to check up on this. M. V. MILLER.

Service Dept.,
Westinghouse Electric & Mfg. Co.,
Indianapolis, Ind.

* * * *

When Should an Armature Be Scrapped Instead of Repaired?—I shall appreciate it if readers will give me their opinion on the following: If an armature needs new coils, a new commutator and a new shaft, especially if it is of the type that has the laminations stacked on the shaft, is a repair job, with only the laminations for a base, a profitable undertaking? Also, when should the core be junked and new laminations used?

Chicago, Ill. J. E. K.

In the April issue, J. E. K. asked for opinions as to when an armature should be scrapped instead of repaired. In most repair shops the cost of re-insulating a commutator completely and rewinding the armature is from one-half to three-fourths the price of a new one. Since armatures are as good as new after rebuilding it is usually considered better to repair them than to buy new ones.

If the armature core is on a spider, a new shaft can generally be put in at a cost not to exceed the price of a new armature. If the laminations are keyed onto the shaft it is generally better to buy a new armature.

It must be remembered, of course, that there is usually considerable delay in obtaining a new armature from the factory, whereas one can be rebuilt in from two to ten days depending on the size and kind. If the iron in the core of an armature gets hot while the winding does not, this is generally an indication that there is an excessive amount of eddy currents, and the laminations should either be re-insulated or junked, preferably the latter.

Peoria, Ill. GEORGE D. RINGNESS.

Building Maintenance and Plant Safety

The object of this department is to give details of building maintenance procedure and best practice in safety work. Articles on ways of handling natural wear and tear or other depreciation, repair methods, rebuilding, extensions, cleaning and painting operations will always be welcome.

Gloves from Old Leather Used for Handling Brick

A CREW of yard men, who were inexperienced in handling brick, wore out several pairs of gloves before they learned how to make an efficient and cheap hand protector out of two pieces of leather, 10 in. by 6 in., with a wrist slot at one end and a finger strap riveted at the other. The hand is slipped through the slot until the fingers come under the strap. The stiffness of the leather holds the glove securely in place.

When the brick must be thrown several at a time, from one man to another, such a protector makes for noticeably speedier handling and also helps to prevent sore hands. Old belts, which are not too stiff, can be used by separating the plies so that the leather is not so thick as to be too stiff to use.

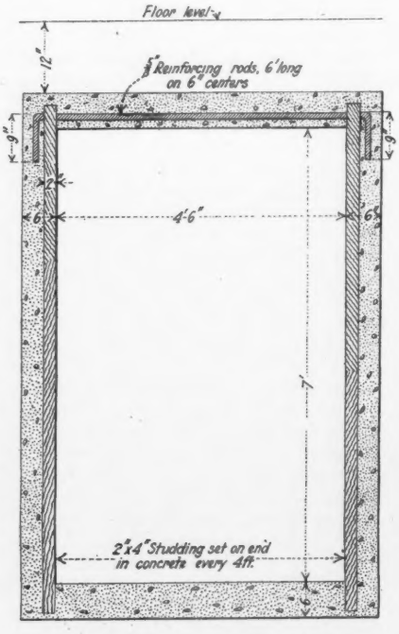
Boulder, Colo. HAROLD E. BENSON.

Construction Details of Tunnel for Conduit and Pipe Lines

IT HAS become common practice to run in tunnels lighting, power, telephone and clock lines, as well as pipe lines for water, air, oil and steam. This simplifies the work considerably when it becomes necessary to repair leaks, replace old sections, install new lines and tap in new branches. The cross-section of a tunnel in one industrial plant is shown in the accompanying sketch. The inside dimensions are 4 ft., 6 in. wide and 7 ft. high, which not only gives plenty of head room, but also allows ample elbow-room for workmen.

The walls, top and bottom are of concrete 6 in. thick with the top only reinforced with ⅝-in. reinforcing rods, spaced about 6 in. apart. The rods are bent near the ends, as shown in the sketch, so as to tie the top into the side walls. Also, 2-in. by 4-in. studs are set in the walls, flush with the inside, about every 4 ft., for attaching the cleats or hangers which are to carry the conduits and small-diameter pipe. These studs should be long enough to reach into the top and bottom slabs of the concrete, to hold them in place. The larger sizes of pipe are run along the bottom of the tunnel, and are supported on suitable rollers to allow free movement due to expansion and contraction.

Manholes with suitable covers are located in the top of the tunnel about every 50 ft., so as to make the tunnel accessible at several points. The ends of the tunnel are fitted with doors through which the long lengths of pipe or conduit can be taken in or out. Wherever necessary, pipe conduits are set in the top of the tunnel through which the wiring and piping lead out into the various departments of the shop. The pipe lines in the tunnel should be fitted with a sufficient number of tees to allow for possible future connections. The wiring can, of course, be tapped at any desired point.



This tunnel for conduit and pipe lines gives ample head- and elbow-room.

The upper surface of the top slab is shown as being 12 in. below the floor line. This allows ample room to install necessary supports, such as sleepers or I-beams, in case a track or driveway has to pass over the tunnel.

Dorchester, Mass. D. FLIEGELMAN.

Advantages of Keeping Diaries on Maintenance Jobs

THE editorial entitled "Job-Diaries on Maintenance Work," on page 491 of the October, 1924, issue was very interesting to us, as we have had such a system as this in operation for about five years. Previous to its installation we found that some question would come up regarding a repair or maintenance job and it would be remembered that this same thing had been gone over before, but no one had saved the exact data on it. This happened so many times that we realized a great deal of time and expense was being wasted in duplicating investigation of the same sort of jobs.

For instance, an order would be received by one of the engineering departments for certain work. The foreman would look it over and then call upon the others interested for a consultation as to the best method of undertaking the job. As a result, from two to six men spent some time in going over the ground thoroughly. We found by experience that this same job would come up again and that it would be necessary to hold another consultation over it, as no one could remember the exact details. Eventually we decided to keep a rough summary of the method used for each job with a notation, when the job was completed, as to how it worked out.

It is impossible to give definite figures as to the savings in money which this plan has made, but we are more than satisfied that it was one of the

best systems ever started in our shop.

We have found that our cost system helps us greatly in connection with this job record, as we can always turn up the cost card on any job and secure therefrom the itemized list of material used and the labor time. These, together with the diary record, give us a very complete story of each job.

This plan has worked out to advantage in another way, and that is its value as a reference for estimating purposes. When used with the cost records it is invaluable for this purpose. We are often asked for an estimate on a certain job which we know we have done before and without any diary or record it would be necessary to make a very careful estimate of the cost. However, a look over the diary enables us to make sure that the jobs are the same; then, after consulting the cost records, we can easily give a very close estimate.

I would suggest that anyone who is contemplating keeping a job diary, such as described, would do well to tie it in with their cost records in some suitable way. In our case this has been accomplished in a simple manner, as every job of work undertaken is covered by an order number assigned on a work order form. This order number is shown in the job diary and also on the cost records, and thus gives us an easy cross-reference. L. J. CLAYTON.

Ass't Mechanical Engineer,
The Goodyear Tire and Rubber Co. of Canada, Ltd.,
Bowmanville, Ont., Can.

Air Hoist Saves Floor Space in Steel Chip Disposal

THE small portable compressed air hoist so frequently used for a variety of jobs in metal mines and by contractors, may also be put to good service in any machine shop or manufacturing plant. The small space and light weight of these machines, combined with their relatively high power, and ease of control, render them adapted to numerous special purposes.

In the new Sullivan Machinery Co.'s plant at Michigan City, Ind., all manufacturing is done on one floor, covering about 200,000 sq. ft. The problem of disposing of the steel and cast-iron chips, turnings and borings of the machines at once presented itself. The cast-iron turnings and borings were readily handled by providing small portable bins or hoppers, equal to a carload when filled. These are placed at convenient points, and their contents dumped, by means of a traveling overhead crane, into a freight car, which is run into the shop.

Disposing of the steel chips, turnings and borings was a more difficult problem, for the reason that the steel scrap is more bulky, and the chips and turnings are very tenacious, so that they interlock when piled together, making it hard to separate them when the pile was to be loaded onto the car. The item of floor space, as well as expense, precluded the use of a baling press. A platform outside the shop was considered, where the waste might be piled and handled into freight cars by using a self-propelling crane with clamshell bucket. However, this would be expensive to operate, and necessitate wheeling the chips a considerable distance.

As floor-space economy was a prime consideration, the scheme shown in the accompanying illustrations was finally adopted. This utilized the overhead space which had previously been of no value. With that idea in view, a steel bin was constructed at a point where it could be emptied into the freight car at one end of the building. This bin was made tapering on the bottom and smooth inside. Its capacity, roughly, equals that of a gondola freight car. The bottom slope is about 30 deg., so that the chips slide out of their own weight. The top of the bin is flat, and about 26 ft. above the floor level. At the discharge end, the bin is 14 ft. high by 10 ft. wide, and at the small end, 3 ft. high by 7 ft. wide by 25 ft. long over all.

The dotted line on the illustration at the left shows the path of the elevator, which operates in vertical guides, and is provided with a hopper or tray with a capacity of a full wheelbarrow load of chips. The hopper is hoisted by means of a Sullivan, single-drum, turbinair hoist mounted on top of the bin, as shown in the other illustration at the right. The drum holds 500 ft. of ⅜-in. wire rope and has a capacity of 2,000 lb. on single line, direct, vertical lift provided by the 6½-hp. turbinair, helical-geared motor. The hoist is operated by a valve situated above the floor and bolted to one of the guides for the elevator. The wheelbarrow men dump their loads of chips on the elevator trays; then they open the valve and the load is raised and the tray or hopper automatically dumped at the top of the hoist by a trip, similar to those used in dumping mine skips or cages. These are lowered by gravity.

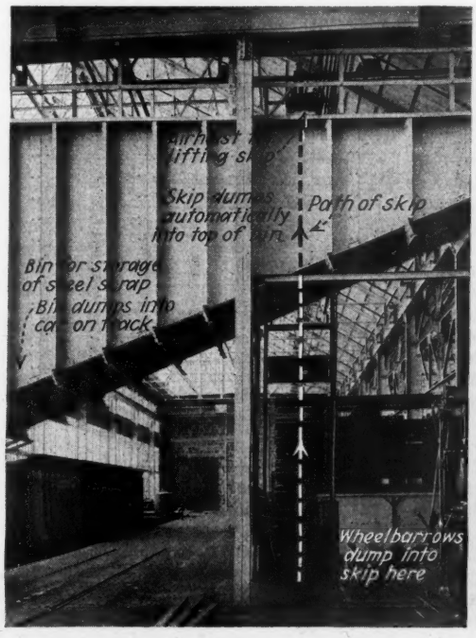
When the bin is full, a car is run under the large end and a vertical door 5 ft. high by 10 ft. wide is opened by means of an air-cylinder hoist, which is shown in horizontal position on the top of the bin in the foreground of the illustration at the right. This door operates like a tail gate on a wagon.

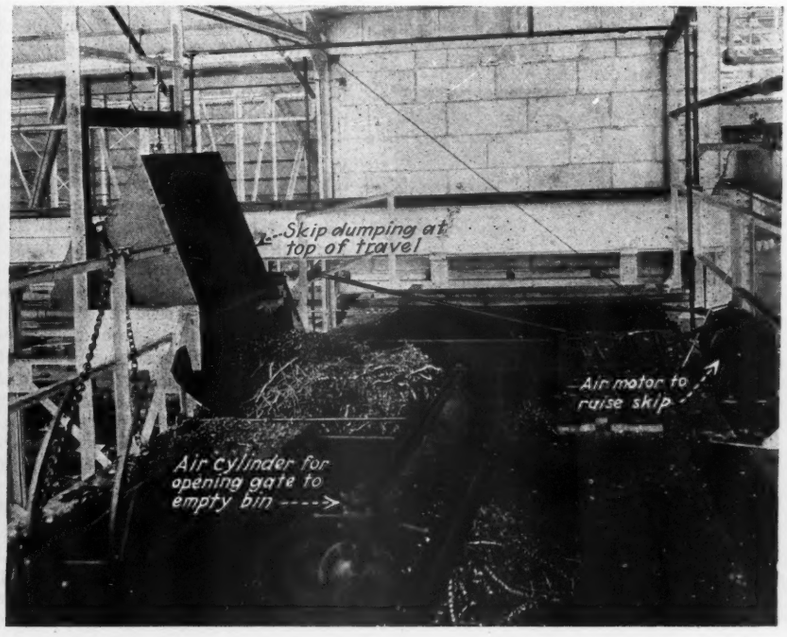
This method of handling chips has saved about 500 sq. ft. of floor space and reduced the cost of handling about 50 per cent. W. H. WINEMAN.

Shop Superintendent,
Sullivan Machinery Co.,
Michigan City, Ind.

Two views of the equipment for steel scrap disposal at the Sullivan Machinery Company's plant.

Steel shavings are dumped from wheelbarrows into the skip which is lifted by an air hoist, as shown by the heavy dotted line at the left, and dumped, as shown at the right, into the top of this large steel bin, with sloping sides and bottom. This bin holds about a carload and is emptied into gondola cars on the track by opening a gate in the lower end of the bin. This gate is raised by a cylinder air hoist. This method of steel shavings disposal not only occupies a small amount of floor space but it has also decreased the former cost of handling about 50 per cent.

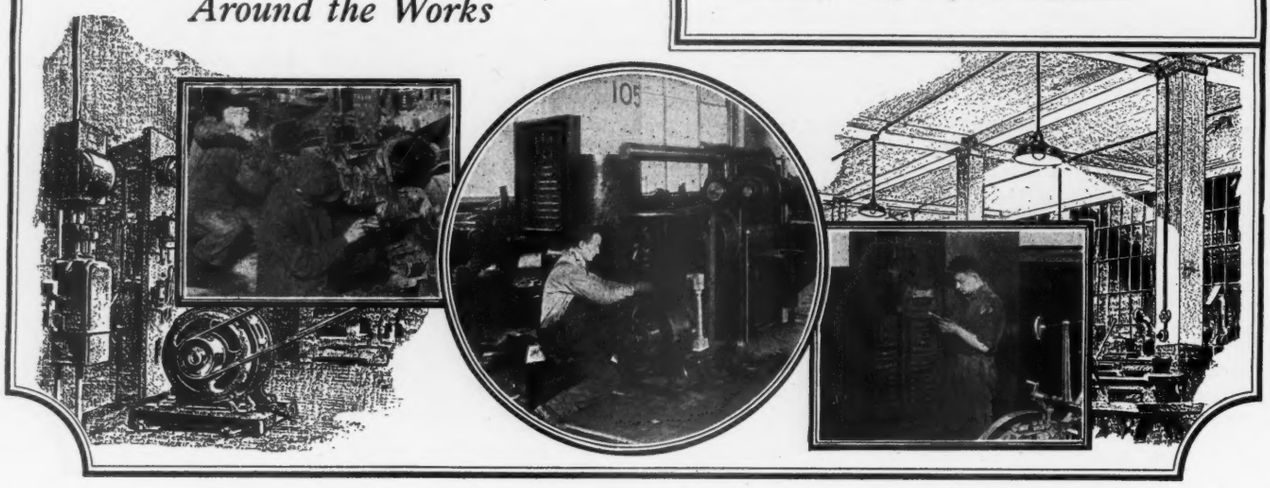

Skip dumps automatically into top of bin
Path of skip
Bin for storage of steel scrap
Bin dumps into car on track
Wheelbarrows dump into skip here



Electrical Service

Around the Works

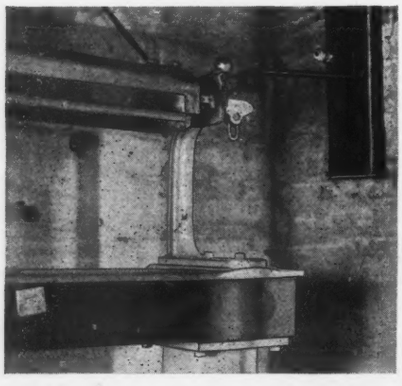
For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.



Contact Device on Scale Beam Tells When Proper Load Is Obtained

LARGE quantities of rough rock salt are shipped in gondola cars from the mines of the Avery Salt Mining Company at Avery Island, La. The cars are loaded by running them over a scale and then starting a motor, controlled by an Electric Controller and Manufacturing Company compensator, which drives a conveyor that dumps the salt directly into the car. Knowing the amount of salt desired in each car, the operator first sets his scale beam to that amount and then takes his position at the loading chute.

On the scale, but in a position that does not affect the accuracy of it, has been placed a very sensitive contactor as is shown in the accompanying illustration. As the scale beam rises to a balance, it closes this contactor and causes a horn to blow. The operator at once shuts off his conveyor motor through a push button switch which trips the compensator.



This contact-making device is located adjacent to the end of the scale beam.

When the scale balances, the beam hits the contact device which closes the circuit on the horn, thus signaling the operator that the proper load has been obtained.

This device could also be used to operate the compensator directly and thus do away with the necessity of the operator listening to the horn and then shutting off the motor himself.

Comment on "Single-Phase Operation of Polyphase Motors"

I WAS much interested in reading W. L. Lodge's comments in the June issue on the article "Single-Phase Operation of Polyphase Motors," and believe with him that it is almost impossible to blow only one fuse of the three protecting a three-phase motor, and thus cause the motor to operate single phase, providing that the fuses are accurately manufactured and *correctly installed*, and motor current is balanced.

However, it is our experience that it is next to impossible to correctly install the 30- and 60-amp. size, ferrule-type fuses, in either the 250- or 600-volt types, due to poor contact of the fuse in the fuse block clips, which point Mr. Lodge refers to in his Item No. 1 under "poor contact." We have a great number of fuse blowouts and also burned cartridges in these sizes, in spite of the fact that fuses are not overloaded and are installed with ordinary accuracy, and believe it is due to the fact that the ferrule contact is not thoroughly satisfactory. A large proportion of them apparently heat enough from the start to draw the temper of the spring to some extent, resulting in poorer contact and more heating, which gets worse until the fuse blows, and finally the cartridge is burned.

It is our opinion that the 30- and 60-amp. fuses should be made with a knife blade contact, the same as larger sizes, as we find no similar trouble with the latter.

We would be glad to see some discussion from operating men and fuse manufacturers on this subject.

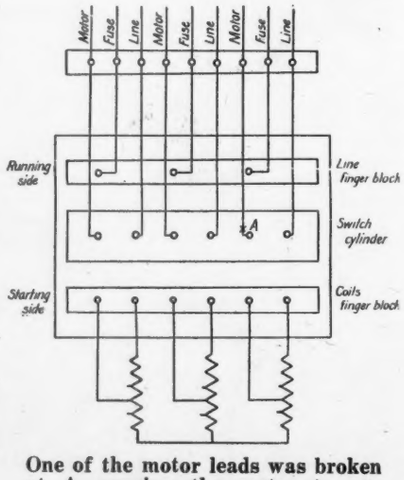
Power Engineer, CHAS. C. COBB, JR.
Walworth Mfg. Co.,
Kewanee, Ill.

Broken Connection Cause of Peculiar Behavior of Three-Phase Motor

RECENTLY a report was brought in to our plant that a 10-hp., three-phase motor driving a quarry drill would suddenly reverse its direction of rotation without warning. As it was impossible to use the drill with the motor running the wrong way, the drill runner would stop the motor; when he started it again it would always start the right way only, however, to repeat the same performance in a short time.

Some of the electricians and others to whom the report was made were frankly skeptical, while the wise ones openly scouted the possibility of such an occurrence. Upon investigation, we found, however, that the report was correct.

The accompanying diagram of the connections to the starting compensator



One of the motor leads was broken at A, causing the motor to run single phase.

Under certain conditions, as explained in the text, the motor would stall and the weight of the drill bit would start it rotating in the opposite direction.

will help to explain the reason for this behavior. As shown at *A*, one of the motor leads was broken just above the terminal where it goes through the switch cylinder. As the lead was rather short it would make contact by touching on the starting side only. When the switch cylinder was thrown to the running position the contact would be broken but the motor would keep on running, single phase.

In these drills the drill bit is raised and lowered by an eccentric. So long as everything went all right the motor, although running single phase, was strong enough to keep the drill going. If, however, the drill bit happened to become wedged or caught in the hole, the motor would slow down and at times the weight of the drill bit would overcome the torque of the motor before the bit had reached its highest point. The motor would then stop and as the bit is raised by an eccentric the weight would start the motor revolving in the opposite direction, and as it was running single phase it would keep on running until it was stopped by the drill runner. When again started by the compensator the motor would, of course, run in the proper direction.

After the broken lead was repaired the motor settled down to the somewhat more humdrum, but also more useful method of operation we have learned to expect from these faithful servants.

J. H. GALLANT.
Canada Cement Company, Ltd.,
Belleville, Ont., Can.

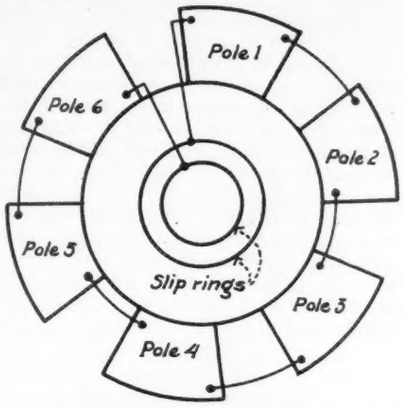
Emergency Method of Operating Synchronous Motor Having Shorted Field Coil

ONE of the troubles that a synchronous motor may develop, is vibration. A machine that has run quietly and smoothly and then develops vibration, indicates either one of two things: misalignment of shaft and bearings, or electrical unbalance due to variation in the magnetic pull exerted by the field. It is advisable, first, to check the alignment by means of a level. If the foundations of the machine have moved, binding will take place in the bearings, accompanied by an increased bearing temperature. If it is found that the bedplate is level, and that the rotating parts turn freely without excessive bearing temperature, it is necessary to look for electrical trouble in the rotating parts.

The means employed to locate the trouble and later operate the machine under reduced load in a case where vibration was rather hard to locate, may be of interest.

The usual checks that were made on the motor indicated that it was accurately lined up. Excessive vibration, however, occurred when the machine was started as an induction motor and the field current applied. Possibility of a short-circuited field coil was apparently discredited, as a voltmeter connected across the individual field coils indicated a uniform resistance for each coil. The machine was then brought up to speed, field applied, and vibration noticed; then the field was cut out, and the machine allowed to coast, when the vibration immediately ceased. This seemed to indicate conclusively that one of the field coils was short-circuited, even though the drop measured by the voltmeter indicated otherwise.

Since a short-circuit between turns in one of the field coils evidently existed when the machine was running, running conditions were approximated by compressing each coil by means of C clamps, the pressure exerted being approximately equal to the centrifugal force due to the speed of the machine. While the coil was compressed the voltage drop across it was measured. This test was unsuccessful inasmuch as it did not show any variation in voltage drop.



Vibration in this rotor was caused by a shorted field coil.

Since the field coil was shorted only while the field was rotating, it was difficult to locate the defective coil. It was found by reconnecting the field coils as described in the accompanying article and then operating the machine to see whether the vibration ceased.

As this was a six-pole machine, it was decided to disconnect the coils on two opposite poles and operate the machine with four salient poles and two consequent poles. In the accompanying diagram, field coils *1* and *4* were disconnected, leaving coils *2*, *3*, *5*, and *6* connected in the field circuit. This connection made poles *2*, *3*, *5* and *6* act as salient poles while poles *1* and *4* became consequent poles. When the machine was operated with this arrangement, no improvement in vibration was noted.

Coils *3* and *6* were then disconnected and *1* and *4* re-connected. Upon starting the machine it was found that the vibration ceased. This indicated that either coil *3* or *6* was causing the trouble. To determine which one of these two coils was at fault, it was necessary to disconnect the even-numbered coils, and operate the motor with the odd-numbered field coils; that is, coils *2*, *4* and *6* were disconnected and the machine operated with coils *1*, *3* and *5*. No vibration occurred on this test. This indicated that coil *6* must develop a short-circuit between turns when it was subjected to compression caused by the centrifugal force of rotation.

It was necessary that this machine operate under reduced load while a new field coil was being obtained from the manufacturer. For several weeks the machine was operated at 60 per cent of its rated load, with four salient and two consequent poles. The maximum load was, of course, determined by the permissible armature and field current, but it was found possible to carry this 60 per cent load with a slight increase over the normal field current and somewhat lower power factor on the motor.

If the field coils are removed from the rotor, it is necessary that the pole pieces remain in the rotor in order to complete the magnetic circuit and maintain the same number of pairs of poles.

The information gained on this job has enabled us to operate at reduced capacity a number of synchronous motors having defective field coils, that would otherwise have been shut down until the new field coil was received.

M. G. REES.
District Service Manager,
Westinghouse Electric & Mfg. Co.,
Detroit, Mich.

Effect of Full-Voltage Starting on Induction Motors

THE effect of full-voltage starting on the windings of squirrel-cage induction motors was discussed by J. T. Rylander of the Westinghouse Electric and Manufacturing Company at a recent convention of the American Institute of Electrical Engineers. His paper gives the results of experimental tests on starting squirrel-cage induction motors on full rated voltage with a study of such starting in service and methods of bracing the end windings. The points of particular interest to readers of INDUTRIAL ENGINEER are abstracted in the following:

It is well known that a heavy starting current is required when starting squirrel-cage induction motors with the customary autotransformer starter. When starting these motors by connecting them directly to the line a starting current that is even heavier is drawn from the line, which, in itself, is undesirable. However, on certain applications it is desirable to have motors start from rest or at some reduced speed without the aid of an attendant when the power on the line fails and then comes on again. This is accomplished by omitting the customary autostarter and connecting the motor directly to the line, thereby impressing on the winding full line voltage, instead of reduced voltages of 50, 65, or 80 per cent.

The effects of full-voltage starting were determined by special tests made on two motors. On these two motors it was found that there was either quivering, vibration or displacement of the windings whenever one of the motors was started. The severity of the motion or displacement increased as a function of the square of the voltage applied to the particular winding; that is, a 440-volt or 2,200-volt motor is no worse off than a 220-volt motor so far as the effect of full voltage alone is concerned, but 440 volts will produce four times as much coil displacement as 220 volts on a particular winding, regardless of the voltage rating.

Starting motors on full voltage pro-

duces a severe stress for a short period, whereas the use of an autotransformer starter produces a less severe stress for a longer period than when starting with full voltage. The auto-starter may produce two severe shocks on the winding in opposite directions. This is accounted for by the voltage, which is produced in the winding, being out of phase with the line voltage at the instant of changing from the lower-voltage tap to the full-voltage tap of the auto-starter.

Observations made on a number of machines that were subjected to full-voltage starting showed that when the effect on the windings is slight, nothing is seen with the eyes, but any quiver or vibration of the windings is felt with the hands without difficulty. Some of these windings not only vibrated but had a definite movement which lasted as long as the heavy starting current flowed through the windings. These movements of the windings were such as to separate the windings wherever the phases change and to cause the winding to move away from the rotor and toward the frame. When the vibration of the winding is severe, a distinct hum is heard.

Some machines which had been in service for years finally failed due to distortion of the windings. The customary auto-starter method of starting these machines had been used. Whether the cause of the distortion was due to the starting current or to some other disturbance, such as short-circuits on the line near the motor, was not known. These windings showed the following effects:

(1) The windings had separated between phases.

(2) The windings had moved away from the rotor and toward the stator.

(3) The top and bottom layers of coils had drawn together.

The separation between phases and the movement toward the frame was also noticed on some of the windings that were observed while they were being started.

The attraction and repulsion of the conductors on each other tends to move the conductors and is opposed by the mechanical fastenings which support the conductors. Many of the conductors are secured by resting them against other conductors, which are secured by various means. As all armature conductors pass through the slots, the slots are an effective means of securing a large part of each conductor. Beyond the slots a number of the conductors are bound together in a unit as a coil, and this prevents the conductors from vibrating against each other. Each coil end tends to move under the effect of the force exerted on it by all the other coils in the machine, but is resisted by the rigidity of the coil as each coil is held by being placed in two different slots and usually fastened at one or more other places on the ends of the windings by means of rope, bolts, clamps or steel bands to other more or less fixed supports.

In many of the small motors the coils fit closely to each other and the complete winding is reinforced with varnish or impregnating compounds; therefore, their windings are exceptionally well braced to resist the forces exerted when starting the motors.

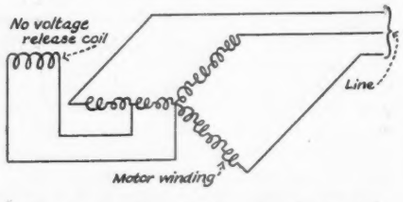
The vibration and movement of the windings deteriorate the insulation, and if sufficiently severe, will cause an insulation failure. They may also break the coil leads.

The kind and amount of insulation and the method of bracing are the limiting factors which determine how much vibration or coil movement can be permitted. The repetition of these vibrations sometimes has a cumulative effect by loosening the rope which is usually used to secure the coils to a supporting ring.

As the amount of vibration or coil movement is directly proportional to the square of the ratio of the starting current to the full-load current, the starting of squirrel-cage induction motors is much more severe on the windings than it is with wound-rotor induction motors, where the current is limited by the resistance in series with the secondary. As the amount of vibration is also directly proportional to the third or fourth power of the length of the coil between supports, very thorough bracing is required where the coil extensions are comparatively large. Nevertheless, there seems to be no question that all induction motor windings can be braced to stand the mechanical effects of full-voltage starting.

Emergency Use of 110-Volt No-Voltage Release on 440-Volt Coil Compensator

RECENTLY, while installing some used motors and compensators, it was found that the no-voltage release coil was burned out on one of the 440-volt compensators. The only spare coil on hand was wound for 110 volts and as the motor which was to be started by this compensator had been connected previously for 220 volts, it was necessary to reconnect it for 440 volts.



By connecting to the neutral and midway between it and a phase lead, 127 volts was obtained for operating a substitute 110-volt, no-voltage release coil on a 440-volt compensator.

It was at length decided to bring out two leads from the winding, as shown in the accompanying sketch. The motor was series-star connected for 440 volts which gives 440÷1.73=254 volts from any phase lead to neutral. By bringing out a lead from the neutral point and midway between it and a phase lead, we obtained 127 volts which operated the no-voltage release coil quite satisfactorily.

Construction Engineer, W. L. STEVENS.
Smith Robinson Co.,
Vancouver, B. C.

Installation of Switchboards

(Continued from page 332)

connection is so overloaded that it will endanger continuous operation.

A regular schedule should be prepared for the periodic testing of instruments, meters, relays, and for the inspection of all other equipment. It is advisable to have a card or blank for this purpose in the form of a questionnaire on which can be noted each point as observed.

The switchboard should be cleaned regularly. This may be done by wiping the apparatus on front of the board and the equipment on the back of the board should be cleaned by dry compressed air of moderate pressure from a hose. If this must be done while the board is alive, extreme care must be exercised.

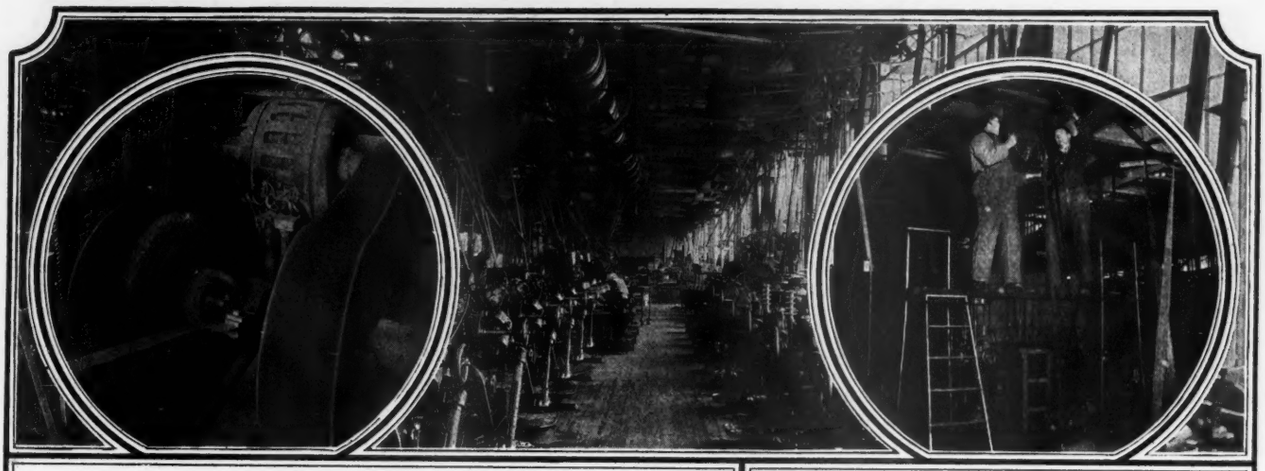
REPAIRING PANELS

To renew the finish of dull black marine slate, black enamel slate, and marble boards, soap and water should be applied with a soft cloth. A marble panel may also be brightened by rubbing with a cloth dipped in gasoline. Oil stains may be removed from polished marble by applying a mixture of benzine and plaster of paris, letting it remain on the stain for 48 hours. Natural black slate may be restored to its original freshness by rubbing with a soft cloth dipped in good engine oil. Only sufficient oil should be used to bring out the good black color of the slate.

To change the finish of a marble panel to match a slate board, the polish should first be removed by rubbing with pumice stone; the surface should then be sprayed evenly with marine lacquer. If the devices cannot be removed, they should be carefully protected. Marine finish may be removed by rubbing with alcohol.

The same kind of drill is used to drill slate or marble as is used for steel, except that the heel of the drill should be ground off to give the drill a sharper angle. Slate may be drilled dry, but marble should be drilled with water. Care should be taken when the drill is coming through the panel, not to break the back surface by too great a pressure on the drill.

Holes left exposed by changes in equipment may be plugged with Portland cement or plaster of paris colored with lamp black.



Mechanical Maintenance of Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through transmitting equipment to all driven machines.

Adapting Grease Cup to Apply Pressure Lubrication

THE grease holes in conveyor and other bearings where dirt easily works its way in, will sometimes get clogged up and thus render the ordinary grease cup ineffective. In such instances I have either modified the construction of the grease cup so that from four to five times the pressure may be obtained, or else used a steel grip on the cup to help screw in the grease. Then by working in plenty of the grease while the machinery is in operation, the dirt will gradually work its way out and cleanse the grease hole for a time.

Of course, this is not a "cure-all" for these dirt-clogging troubles, but where there is insufficient shut-down time to scrape out grease grooves or to make other permanent repairs to keep dirt out of the bearings, it is wise to keep the modified cup screwed into the grease hole.

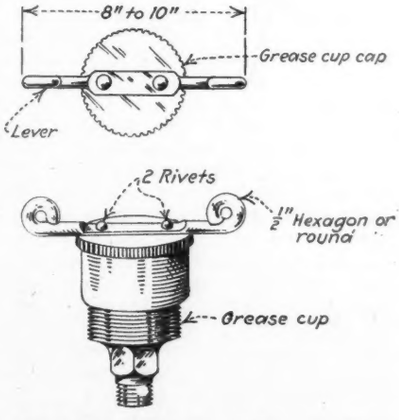
The lever, which is riveted onto the top of the grease cup, is forged out of ½-in. to ⅝-in. round or hexagonal steel to the shape shown in the accompanying sketch, with the ends turned to provide a good hand grip. The central portion where it fits over the cup is flattened out to slightly over ¼ in. thick. This flattening or widening leaves sufficient stock after the rivet holes are drilled out. It may be necessary to provide additional stock by upsetting the steel at this section, as a tremendous bending moment occurs at the rivet holes when forcing the grease through any obstruction.

If the rivet holes are well laid out in both the grease cup and its lever and the riveting carefully done, there will be no decrease in pressure by any grease escaping at this point.

The selection of a grease cup with good threads and a thick shell is of importance, when deciding to modify its construction in this manner, or else the high pressure thus obtained is apt to spring or stretch the shell and cause the cup to jump threads and become ineffective. For this reason, pressed-steel cups are better for this purpose than those made of brass. Cast-iron cups are also good since they are usually made thick, but care must be exercised in riveting the lever on so as not to crack the cast iron.

A handy grip which may be used to screw down grease cups which are close up against a shoulder so that the lever grip shown cannot be used, may be made from a piece of steel bent to fit around the cap of the grease cup, similar to the clamp used to open the common Mason glass fruit jar. This is made by taking a piece of ½-in. round steel about 17 in. long, flattening it out in the center for a distance of about 4 in. and bending this flat part to fit around the grease cup until the ends of the rod are parallel. This leaves two handles each about 8 in. long which may be squeezed to clamp the cap. The flat part may be serrated on the inside to make it grip on the serrations on the grease cup.

Oakland, Calif. S. H. SAMUELS.



By riveting levers on the top of a grease cup, giving it the appearance of a wing nut, higher pressure may be applied than ordinarily is possible when turning by hand.

Lubrication of Ball Bearing Hanger Boxes

WHERE ball bearings are being used in shaft hangers, motors and other power drive equipment, the lubrication requirements are not as well understood as for the plain sleeve bearings. The tendency is to overlubricate the ball bearings. They operate best when the balls and races are just coated with a film of oil or grease. But since it is not a practical matter to regulate the supply with certainty so closely as this, there is no reason to go to the other extreme and suffocate ball bearings with lubricant. When too much grease is applied too frequently, the new grease will simply force out the old lubricant and provide a place for the collection of dirt and dust and make a messy looking bearing housing. The application of lubricant to lineshaft hanger boxes using ball bearings is recommended not oftener than every three or four months depending how continuously the shaft is actually revolving in its hangers and the load on it. For lightly-loaded shafting not in continuous use, the application of lubricant about every nine months is sufficient.

On the lubrication of ball bearing hanger boxes, the Fafnir Bearing Company, New Britain, Conn., offers the following recommendations and sidelights:

"Fafnir double ball bearing, hanger boxes and other Fafnir transmission units are shipped from the factory containing all the grease which they ought to have for six months under average conditions. In fact we use a little more grease than is needed, believing that it is well to supply an excess of lubricant to guard against possible contingencies while the bearings are new.

"It may seem to the reader that we are going to considerable pains to explain what is really a simple matter that anyone can readily understand with a few words of explanation. However, we know from actual experience

that the mill or factory operator is apt to be unduly conscious of the presence of his new hanger boxes. It is much the same as it is with the man who has just bought a new car. He listens to every murmur of the motor and his ears are strained for squeaks. After a few miles he thinks the valves may need grinding or, more to the point, that the oil has leaked out of the crankcase. The consequence is that for the first few weeks he makes frequent trips to the service station and asks every question imaginable—and many that surpass his normal thinking powers. But after the strangeness has worn off he never visits the service station.

"It is apt to be much the same with the man who has just installed Fafnir double ball bearing, hanger boxes. He worries too much for fear that they may need oil. If he hears a squeak it may be because the hanger screws have worked loose a little, but after thinking about it he is pretty sure to decide that it is time to grease the bearings. As one mill man said to the writer recently—'I know you said these bearings wouldn't need any more grease for a year, but I'll be darned if I am going to see them ruined.' He had been filling them up with grease every four weeks.

"Finally, we want to emphasize the importance of using a proper lubricant. For ball bearing use, avoid lubricants which are sticky and will gum up the bearings. Never use what is called black strap. Moreover, the lubricant should be free from graphite which will pack in the bottom of the race grooves and interfere with the free rolling action of the balls. Lubricants containing animal fats which are liable to develop acids will corrode and etch the highly polished ball and race surfaces.

"The ideal lubricant is one having a mineral base and which is absolutely neutral,—that is, neither acid nor alkaline. For very slow speeds a grease should be used, and for high speeds, an oil. For Fafnir double ball bearing, hanger boxes used on line shafting, where speeds are usually neither low nor very high, in general a neutral non-fluid oil made from a mineral base, the consistency of which is about like vaseline, is best. There are a number of brands of high-grade lubricants of this character on the market, any one of which will give good results."

Simple Chart for Finding Pulley Sizes to Give Various Speed Ratios

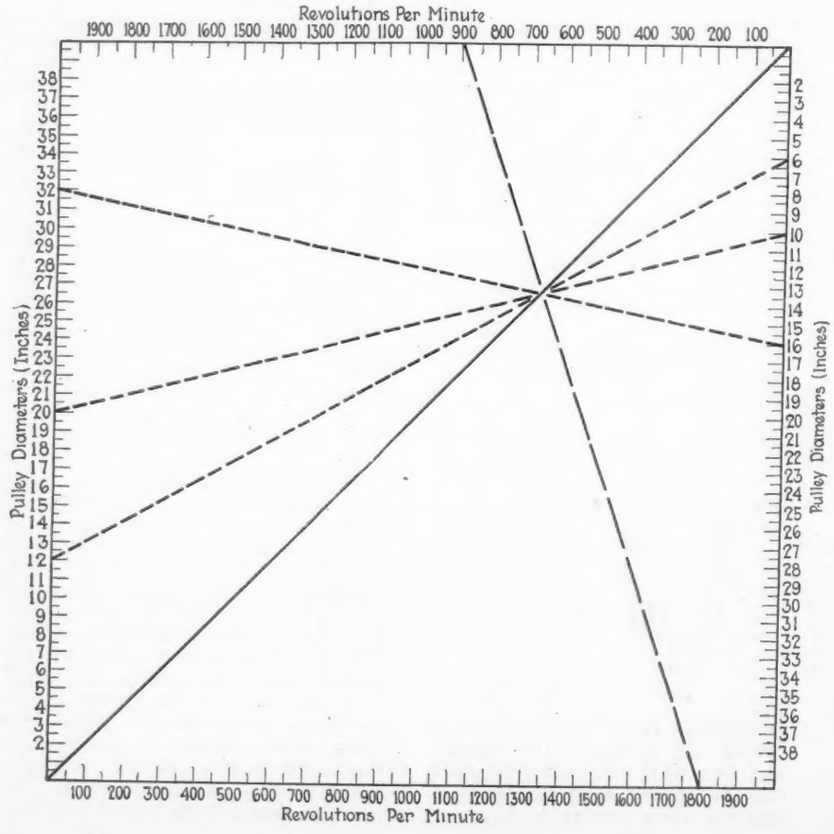
IN MAKING changes in belt speed, it is frequently desirable to make a quick check to see how closely some of the pulleys available will give the desired speed, if used. One method of doing this is by the use of a chart such as is shown in the accompanying sketch. This pulley chart is made up in the form of a square with a scale on which each 100 revolutions are equal to two units representing the diameter of the pulley in inches, arranged as shown.

Suppose that with a motor speed of 1,800 r.p.m., a speed of 900 r.p.m. is desired for the machine which it drives. The first step in locating the approximate pulley sizes would be to place a straightedge on the scale at 1,800 and 900 r.p.m., as shown by the longer dash line. The point of intersection with the diagonal is then used as a center or axis and the straightedge laid through it. When the straightedge passes through this center point the readings on each side indicate pulley diameters which will give this ratio of speed changes. In this way, it is possible to test out quickly a variety of pulley sizes to see if any usable combination can be made up of those on hand.

While this scheme is a part of a recommendation on the calculations used in designing textile machinery, Technologic Paper of the Bureau of Standards, No. 282, the ease with which it may be constructed and used in industrial work is obvious. If this chart is to be used very frequently it would be advisable to redraw it to a considerably larger scale, and with more r.p.m.'s and diameters given. In case it is desired to protect it, the chart may be shellacked which makes it waterproof and easily cleaned. The chart in that case must, however, be mounted on heavy wallboard.

With this pulley chart combinations of pulleys to give any required speed ratio may be easily computed.

To find the combination of pulley sizes which will give a special speed when the speed of one pulley is fixed, simply place a straightedge on the horizontal scales, which represent the two speeds, as shown by the heavy dash line. The point of intersection of the straightedge with the diagonal is then used as a center and the straightedge rotated on this center indicates the possible combinations of pulley sizes which will give the required ratio. Three of the possible combinations are shown by the short dotted lines.



Helps on Running-In Bearings Which Heat Up When New

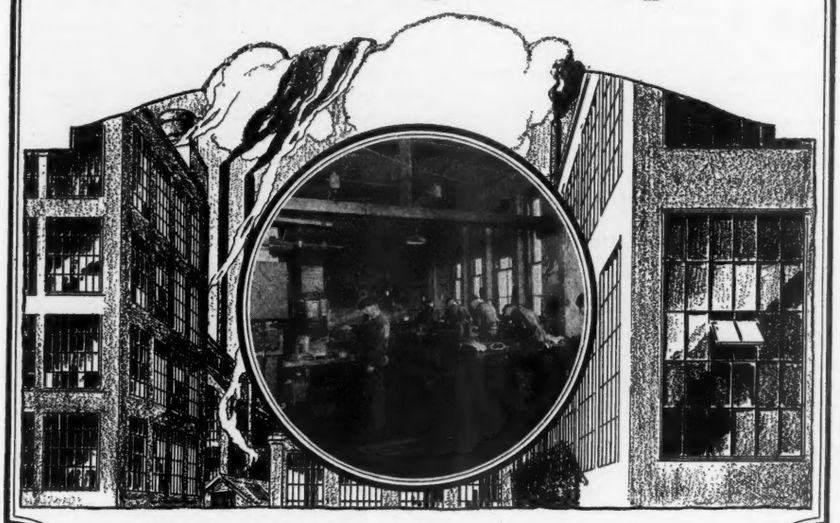
RECENTLY, I found a way of working down new bearings when they overheat on the first run, without any apparent cause, which may be of service to some other reader of INDUSTRIAL ENGINEER. My remedy for this condition is to pulverize a cake of Sapolio or Bon Ami and mix it with the oil which is being poured into these bearings. This is all washed out after obtaining the desired relief and replaced with fresh, clear oil. On extremely bad cases of overheating with new bearings, I have used Dutch Cleanser.

This heating has been attributed to using mandrels which are not perfect and give a somewhat eccentric interior bearing surface. This permits the bearing to turn freely along the shaft but it seemingly freezes on being fastened down in the bearing housing. My experience with graphite is that it does not wash out well afterward and to a great extent remains in the oil pasages within the housing.

One way to clean and reclaim this oil, which contains the Sapolio solution and also that which has been used in washing out the bearing, is to empty it into an old felt hat placed upside down over a large can. The hat acts as a strainer and need only be washed every month or so with gasoline.

Coatesville, Pa. -M. J. E.

In the Repair Shop

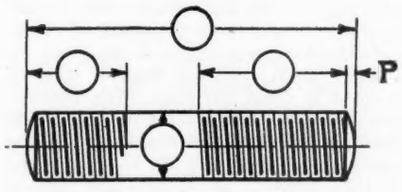


This section is devoted to repair work, large and small. Special attention is given to shop or bench tools and short cuts or improved methods. Contributions are always welcome.

Dimension Specification for Ordering Stud Bolts

NO MATTER what the product of a factory is there is one element necessary before service in the way of delivery can be given to the purchaser. That element is complete specification data.

Where a product is standardized there is, of course, less chance for misinterpretation of the order than where the product is individual to each consumer. In the case of ordinary stud bolts, for example, it is not unusual for the customer to assume that, in giving the over-all length and diameter of the bolt, he has given sufficient data for fulfillment of the order. Consideration of the following facts will show that this is not true: (1) Proper thread length for both the tap and nut ends of the bolt is essential for its use in a particular case. (2) No standardized length of tap and nut ends is recognized for a given over-all length and diameter of a stud bolt. (3) A large percentage of this type of bolts is special both as to size, and length of thread wanted. (4) Methods of measurement of the length of the tap and nut ends differ; that is, the tap length is measured *through* the point, while the nut end is measured *to* the point. (5) The importance of specifying point measurement is frequently overlooked.



"P" = 1/32" FOR 5/16" AND SMALLER
"P" = 1/16" " 3/8" TO 1/2" INCLUSIVE
"P" = 3/32" " 9/16" " 3/4" "
"P" = 1/8" " 7/8" " 1 1/8" "

Use of this form simplifies the specification of stud bolts.

The four important dimensions that should be given are indicated by the circles. The dimension *P* is the width of the point. This dimension has been standardized as indicated in the table under the diagram.

In consequence of the failure of many purchasers to give either sufficient, or the right kind, of information when ordering stud bolts, many bolt and nut manufacturers have developed their own methods of interpreting specifications. Some have even adopted a standard of their own in which a given over-all length and diameter of the bolt represent a definite length of the tap and nut ends. Difficulties attend the use of this, however, as it is not commonly employed or commonly recognized as a standard.

The method which we employ in the case of a customer who orders many special studs, is noteworthy because of its success in eliminating errors. A small blue-print, which is about 4 in. by 6 in. in size and of the form shown in the accompanying illustration, has been made showing the threaded portions, blank area and the points at the end of a stud bolt. The dimension lines, it will be noted, have been drawn in the print for each of these items, but the space for the figures has been left blank. The three items below the stud diagram give the point dimensions (in width) for the various sizes of bolts. It will also be noted that the dimension for the tap end of the bolt extends through the point, while the dimension for the nut end extends only to the point. The dimension for the point itself constitutes a separate item.

A large number of these blank blueprints are kept on hand by the customer. When ordering stud bolts the dimensions desired are filled in on one of these blueprints which is then sent along with the order.

There are several advantages connected with the use of this method of ordering. Briefly, they are: (1) Elimination of all possibility of misinterpretation by the manufacturer. (2) Rapidity with which the dimensions can be filled in. (3) Elimination of time lost in writing the manufacturers for further information.

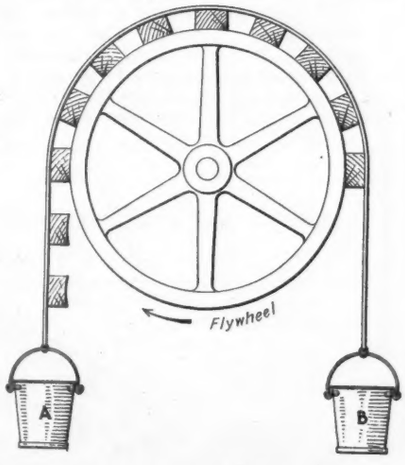
Buffalo Bolt Co., ARTHUR L. GREENE.
North Tonawanda, N. Y.

Simple Prony Brake for Testing Small and Medium Sizes of Motors

SOMETIMES, in testing small and medium sizes of re-wound motors, it is desired to subject them to a load test. This is often inconvenient to do because of the lack of a dynamometer or a generator to which the motor may be belted so as to provide a load. When this is true the best method of obtaining a load is by the use of a Prony brake.

A very simple form of Prony brake that can be easily made in the repair shop is shown in the accompanying illustration. The motor to be tested is fitted with a large pulley or flywheel. A piece of leather belting long enough to wrap around the flywheel, as shown in the illustration, is fitted with soft wood cleats. These cleats may be fastened to the belt by means of wood screws. Buckets are then attached to each end of the belt, as shown.

In running the test the flywheel should be gradually brought up to speed and at the same time the two buckets should be balanced by adding iron, bolts, nuts, scrap iron, rock, or other small, heavy objects. Naturally more weight will have to be added to bucket *A* so as to resist the pull of the flywheel on the cleated belt. Weights



The brake is made by fastening soft wood cleats to a piece of leather belt.

This belt is placed around a pulley or flywheel attached to the motor shaft. By adding weight to the buckets which are fastened to the ends of the belt the desired amount of load may be obtained.

are added to bucket *B* so as to obtain more friction between the flywheel and the cleats, thereby putting more load on the motor. When the desired amount of load has been placed upon the motor, as indicated by an ammeter connected in the supply to the motor, and at the same time the buckets have been made to balance, determine the speed of the flywheel by means of a revolution counter.

The horsepower delivered by the motor at the motor shaft may then be determined by the following equation:

Hp.=3.1416×D×r.p.m×(A—B)÷ 33,000.

In this equation,

D=diameter of flywheel

A=total weight of bucket *A* and its contents

B=total weight of bucket *B* and its contents

r.p.m.=revolutions per minute of motor shaft

As an example let us say that the diameter of the pulley or flywheel was 2 ft., and that the motor speed was 1,200 r.p.m., when the buckets balanced. The total weight of bucket *A* was found to be 80 lb., while that of *B* was 10 lb. Then the horsepower developed by the motor during this test was 3.1416×2×1,200×(80—10) ÷ 33,000= 16 hp.

In making this test it is a good idea to nail strips of wood on the ends of the cleats at two or three points, so as to prevent the brake from slipping sideways.

Some objection to this form of brake might be raised because a downward thrust is placed on the motor bearing by the weight of the two buckets, which will cause increased friction at the motor bearings. This would not be the case if the motor output were determined by the usual form of prony brake. However, this increase in bearing friction is quite small, especially when compared with the full-load rating of the motor. Also, the same increase in bearing friction is encountered when the motor is belted to its load, as the pull of the belt must be borne by the bearings, so that this test will give a close approximation of the performance of the motor under normal operating conditions.

Oakland, Cal. S. H. SAMUELS.

How Babbitt Oil Rings Were Cast and Turned Down

TWO very old motors which were brought in to us for repairs, required, among other things, the replacement of eight oil rings. These were of white metal, which the owner insisted was babbitt and, as he would allow nothing else to be used, we made the rings from genuine babbitt. Because that metal is not very strong and is difficult to handle in the lathe, the method used may help some other readers.

The rings were ⅜ in. wide, 3 in. inside and 3½ in. outside diameters. A mandrel was made by cutting a piece of oak about 1 ft. long and putting big centers (regular 60-deg. bevel) in each end. These centers were large enough to stay true when turning and changing in the engine lathe. This mandrel was turned to a diameter of 3 in. for more than half its length and carefully smoothed up.

In order to make good, solid rings, it was decided to stand the mandrel vertically and to surround it with a piece of steel tubing, 3¾ in. inside diameter. This tubing was smoothed inside with emery cloth to make it slippery and was painted inside with red lead. Both tube and wooden mandrel were faced square on one end, so that they could be clamped upright on the planer table, and centered with a scale. The babbitt was then poured.

After the tube had been pressed off, it did not adhere tightly to the babbitt, due to contraction of the latter and the coating of red lead on the inside of the tube, the shell of babbitt remained on the wooden mandrel. This was put in the lathe and was found to run as true as when turned. The excess babbitt was turned off until the shell was concentric and reduced to the required diameter. The roughness of the wood and the contraction of the metal were sufficient to hold it in place for turning.

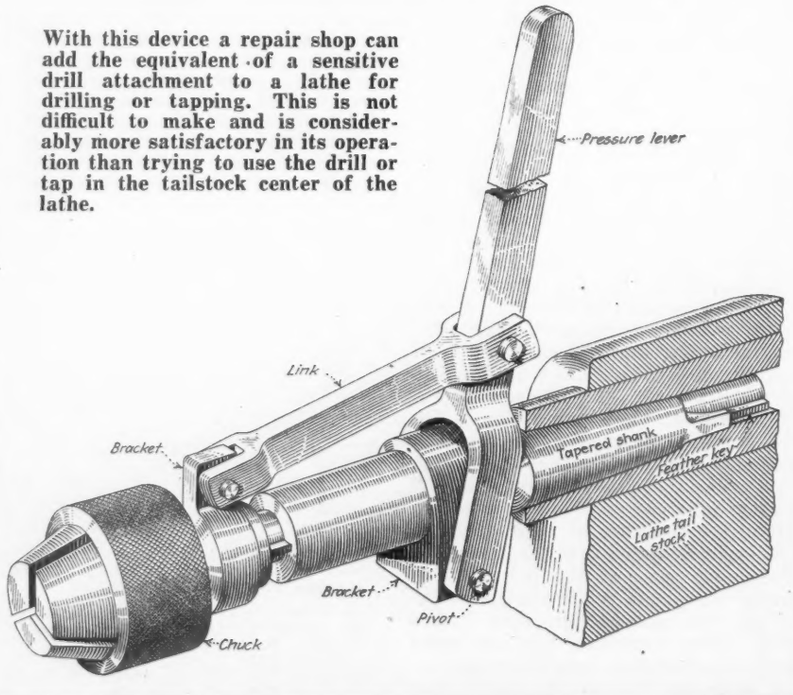
Finally, a ⅛-in. parting tool was used to divide the shell into rings. Thin slices of babbitt-bound wood were then cut off with a hacksaw. The wood centers were removed by drilling a few holes and splitting out with a knife. The slight roughness inside was smoothed with a scraper and the rings were ready. It was a matter of satisfaction that these rings were made without distorting them and that they ran perfectly when put into service.

DONALD A. HAMPSON.

Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Easily Constructed Sensitive Drill and Tapping Attachment for Lathe

With this device a repair shop can add the equivalent of a sensitive drill attachment to a lathe for drilling or tapping. This is not difficult to make and is considerably more satisfactory in its operation than trying to use the drill or tap in the tailstock center of the lathe.



SMALL repair shops often do not have an extensive line of machine tools and the ingenuity of the men is frequently taxed to devise special attachments for doing unusual work. One operation, for example, which they are frequently called upon to do, is to drill or tap parts in the lathe. In shops without special attachments the usual method of drilling with the lathe is to place the drill in the tailstock spindle and use the tailstock feed to move the drill into the work. It is more difficult, however, to use a tap in the tail stock of the lathe in this way on account of the tendency of the tap or chuck to pull out of the socket when backing off.

One means of attaching a sensitive feed to the tailstock of a lathe is shown in the accompanying sketch, which illustrates a device which one repair shop man made to do this kind of work. As will be seen a chuck is mounted on a solid shaft, with a feather key to prevent it from turning. The connection to the lathe spindle is made through a hollow tapered shank of the usual size. The key is also attached to this shank. A single link and a pressure lever are fitted with small brackets, as shown in the sketch at the left.

The drill or tap is moved forward by the lever, without forcing, and only as required. The parts comprising this device are simple and do not require any difficult machine work or the making of any castings. Drilling and tapping operations may be carried on with this fixture with a facility equal to that afforded by the sensitive drill press, which makes it a very desirable lathe fixture for general use.

Washington, D. C. G. A. LUERS.

Hoods and exhaust systems on a fur cleaning bench.

Each bench is supplied with its individual exhaust system and outlet so that either may be used irrespective of the other. The hoods catch any dust or hair which may be loosened during the cleaning process and draw it away from the operator before it escapes into the room. The suction brush which is used for cleaning the fur is on a separate exhaust system, as it requires a much higher suction pressure than is needed for the hood.

Removing Dust in Industrial Plants

(Continued from page 326)

employed, and suctions less than the maximum noted above will be the rule, in the average case.

Centrifugal exhausters used for this class of work are generally of the stage or turbine type, in which a number of narrow fan wheels are mounted side by side upon the same shaft, so as to operate in series, the same as a centrifugal pump with multiple impellers. Low-pressure exhausters of this type are commonly designed for suctions up to 25 or 30 in. of water column, and high-pressure machines for 100 in.

Another form of exhauster used quite extensively in this work is the rotary type. This is a positive-pressure machine, and some forms are capable of operating satisfactorily under pressures up to 5 or 6 lb. per sq. in.

Pneumatic sweeping is made use of in all kinds of factories and mills where fine dust and lint settle upon the building construction and its contents. Its advantages are obvious, as it sweeps without raising a dust, and collects the waste material for disposal without moving it from place to place within the room. Sometimes, however, in certain places difficult of access around shafting and in intricate machinery, such as motor or generator windings, it is necessary to blow the dust or lint out with a jet of compressed air and then collect it with the sweeper. This is best accomplished by a jet of air, not exceeding ⅛ in. in diameter, under a pressure of about 30 lb. per sq. in. For some equipment this pressure is too high.

Jets from compressed air lines are sometimes used. However, as compressed air generally contains moisture, it is not safe to use around live electrical equipment. Also, the pressure is generally too high although many plants use it.

When employed in textile mills for cleaning machines and shafting, the air current should be directed downward, in which case the heavy lint will fall directly to the floor without being blown about the room. Equipment for this purpose is usually of the portable type. Similarly trucks are equipped with pneumatic sweeping equipment, this being much cheaper in many cases than installing an extensive system of piping connected with a stationary plant. Sweeping and blowing machines are often combined in the same unit by the use of valves for reversing the flow of air through the inlet and outlet pipes.

Types of portable hand blowers and one combination portable blower and vacuum cleaner are available for this purpose. These are attached to a light socket and held in the hand while the blast of air is directed into the machine through a long

Table I—Minimum Sizes of Branch Pipes for Emery or Other Grinding Wheels

Diameter of Wheels	Maximum Grinding Surface in Sq. In.	Minimum Diameter of Branch Pipe in Inches
6 in. or less, not over 1 in. thick	19	3
7 in. to 9 in., inc., not over 1½ in. thick	43	3½
10 in. to 16 in., inc., not over 2 in. thick	101	4
17 in. to 19 in., inc., not over 3 in. thick	180	4½
20 in. to 24 in., inc., not over 4 in. thick	302	5
25 in. to 30 in., inc., not over 5 in. thick	472	6

Note:—The sizes of connections suggested for grinding and polishing wheels are those given in the tables by the Department of Labor of New York, with the exception of those for polishing wheels 21 in. and over in diameter. Specified pipes are without fractional inch diameters to agree with common practice.

Table II—Minimum Size of Branch Pipes for Buffing, Polishing or Rag Wheels

Diameter of Wheels	Maximum Grinding Surface in Sq. In.	Minimum Diameter of Branch Pipe in Inches
6 in. or less, not over 1 in. thick	19	3½
7 in. to 12 in., inc., not over 1½ in. thick	57	4
13 in. to 16 in., inc., not over 2 in. thick	101	4½
17 in. to 20 in., inc., not over 3 in. thick	189	5
21 in. to 27 in., inc., not over 4 in. thick	338	6
27 in. to 33 in., inc., not over 5 in. thick	518	7

Note:—Where the branches are extremely long, the friction loss in the system may be decreased by making pipes ½ in. greater in diameter than the sizes given in above tables.

nozzle. They are designed primarily to clean electrical apparatus and to remove the dust or lint which settles in the windings. It would be almost impossible to remove this in any other way. Switchboards, relays, and other electrical equipment are also cleaned in the same way. The use, however, of these blowers is in no way restricted to electrical equipment.

Methods of removing the dust from the air supply and the exhaust system, which require the use of filters, will be taken up in another article to appear later. The problem of handling heavier materials such as shavings, cotton, wool, bark and so on will also be discussed in a later issue.

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Trade Literature
You Should Know About

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Wall Receptacles—Bulletin 53 describes the wall receptacles, plugs and cable connectors made by this company for use in industrial plant and other buildings.—Russell & Stoll Co., 53 Rose St., New York City.

Repair Parts for Meters—Part List 9, gives the price list of repair parts for Type H watt-hour meters and single-phase and polyphase meters, service and switchboard types.—Sangamo Electric Co., Springfield, Ill.

Speed Reduction Units—A booklet entitled, "Speed and Power," describes and lists the Boston herringbone and worm gear speed reduction units.—Boston Gear Works Sales Co., Norfolk Downs, Mass.

Lift Trucks—A 12-page bulletin describes the four-wheel Plimton elevating-platform hand-trucks which are manufactured in 33 sizes. The front wheels are mounted on automobile type steering knuckles.—The Plimton Lift Truck Corp., Stamford, Conn.

Snap-Switch Rheostat—A folder describes a combination snap-switch and rheostat for use in connection with small fans, buffers and grinders, small lathes, winding machines, lamps and motors, soldering irons, glue pots and other appliances.—National Electric Controller Co., 154 Whiting St., Chicago, Ill.

Machine Molded Gears—A folder shows how the Poole machine molded gears are made and illustrates some of the variety of gears manufactured in this way.—The Poole Engineering & Machine Co., Baltimore, Md.

Chains and Gears—Section 27 is a 224-page catalog of the chains, sprockets and gears designed and supplied by this company for use in connection with their conveyors and other equipment.—Stephens-Adamson Mfg. Co., Aurora, Ill.

Wood Boring Machines—Literature describes a new lightweight, reversible pneumatic wood boring machine which is suitable for boring holes up to 1 in. in diameter.—Ingersoll-Rand Co., 11 Broadway, New York City.

Non-Metallic Heating Elements—A technical bulletin describes the Globar non-metallic heating unit, gives charts and tables of ratings and shows a large number of standard types of elements used in the electric heating field.—American Resistor Co., Milwaukee, Wis.

Hollow Seamless Balls—Folders describe the method of manufacture of hollow seamless balls made in one piece from steel, brass, bronze, copper, aluminum, monel metal, stainless steel, or any other metal, together with some of the applications.—Hollow Ball Co., Inc., Baltimore, Md.

Automatic Cable Take-Up Reel—Bulletin 1000 describes the C.A.W. automatic cable take-up reels for handling and preserving cable, such as is used on lifting magnets and other portable electrical equipment.—Cleveland Armature Works, Inc., 4732 St. Clair Ave., Cleveland, Ohio.

Truck Casters—Catalog K-8 describes the various types of anti-friction truck casters which are provided with ball races in the swivel and roller bearings in the wheel. One type has both ball and roller bearings in the swivel.—Bond Foundry & Machine Co., Manheim, Lancaster County, Pa.

Roller Bearings—A folder describes utility roller bearings which are made in standard sizes for general use, and gives dimensions and price lists.—Rollway Bearing Co., Inc., Syracuse, N. Y.

Safety Ladder Shoes—A folder describes a cork-grip, non-slipping safety shoe for attaching to the foot of ladders. When attached, this shoe is hinged so that it does not interfere with the use of the ladder.—The Safety Service & Engineering Co., 5716 Euclid Ave., Cleveland, Ohio.

Storage Batteries for Trucks and Tractors—A 16-page booklet entitled "The Adaptability of Electric Industrial Trucks and Tractors" illustrates and describes some of the numerous applications of electric trucks and tractors. A 28-page booklet entitled, "Selecting a Battery for Electric Industrial Truck Service" gives the points to be considered in selecting a battery for this type of equipment, shows by means of charts the operating characteristics, and discusses electrical efficiency, maintenance care and cost and other battery problems.—The Electric Storage Battery Co., Philadelphia, Pa.

Waterproofing Treatment for Belts—Circulars describe Belt-Sek which is a special belt treatment that can be applied to belts on the pulleys for waterproofing them. In addition, it is claimed that this treatment will lengthen the life, prevent slipping and clean the belt as well as put new life into dry, brittle or cracked belts. Other circulars describe different products which waterproof and preserve canvas, cotton textiles, and other fabrics and materials.—Sek Manufacturing Co., 4301 W. Kinzie St., Chicago, Ill.

Handbook of Mechanical Rubber Goods—A handbook of 160 pages describes the various Goodyear mechanical rubber products such as belts, hose, packing, molded and lathe cut goods; 56 pages are devoted to a discussion of Goodyear belting, its applications, methods of fastening, care, how it is made and its use.—Goodyear Tire & Rubber Co., Akron, Ohio.

Wiring Manual—A 150-page, pocket-size handbook contains tables and a large amount of data for ready reference by electrical engineers, contractors and wiremen, in addition to information regarding Simplex products.—Simplex Wire & Cable Co., 201 Devonshire St., Boston, Mass.

Safety Switches, Wiring Devices, Switch and Panelboards—Catalog 13 is divided into four sections, taking up the following subjects: safety switches; open knife switches and accessories; porcelain wiring devices, panelboards and cabinets. This catalog contains 195 pages including the index, and gives a number of diagrams as well as descriptions and illustrations of the equipment.—The Trumbull Electric Mfg. Co., Plainville, Conn.

Care of Rope—Pocket size circulars explain the proper care of manila rope, show how to uncoil it and give a price list.—Columbian Rope Co., Auburn, N. Y.